

Living Ground

A Vision to Restore Carbon for Healthy Agricultural Lands

SEPTEMBER 2026

Carbon180

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Executive Summary

Our vision for the future is one that centers soil and ecosystem health, repays the carbon debts accrued over generations of land use shaped by unsustainable incentives, and creates resilient agroecosystems that support production alongside thriving ecosystems and communities.

Farmers and ranchers in the United States today face many pressures: barriers to accessing land, market volatility and shrinking profit margins, and rising input costs. Our farms are productive in a short-term sense while vulnerable in the long-term to degrading soils, chemical pollution, and declining water quality and supply. These pressures are compounded by climate change, which intensifies extreme weather.

Yet agriculture is not only exposed to climate change. It is also one of the largest sources of emissions in the country, while holding great potential for helping combat climate change. Scientists estimate that, alongside rapid emissions reductions, the world will need 5–10 gigatons of carbon dioxide removal (CDR) each year by 2050 to keep warming within 1.5°C. US croplands and grasslands already draw down 20–50 million tons of CO₂ equivalent (MtCO₂e) per year, equal to 3–8% of the sector’s own annual emissions.¹ Their untapped potential is far greater.

Transitioning from annual commodity crops towards systems with more diverse, perennialized approaches — including agroforestry, cover crops, and permaculture — would build soil and ecosystem health, increase carbon storage, and strengthen resilience to extreme weather.



HUDSON FARM, PHOTO BY COURTNEY FEE

Moderate adoption of conservation practices across 175 million acres can remove 106 million metric tons of CO₂ equivalent (MtCO₂e) per year over the next two to three decades. Broader adoption on 336 million acres could remove 204 MtCO₂e, assuming sufficient economic incentives, technical guidance, and social support.² Enhanced carbon sequestration would help offset up to a third of the 10% of total US greenhouse gas emissions contributed by agriculture. If pairing conservation practices with measures that cut emissions, US agriculture could even become carbon neutral.³

Newer pathways such as biochar and enhanced rock weathering (ERW) have the potential to further scale carbon removal at more durable timescales — though more research and demonstration is needed to confirm the ability to scale these pathways sustainably.

Over 2024 and 2025, Carbon180 convened listening sessions with more than 200 land stewards across the country, and interviewed scientists and technical service providers on the science and practice of agricultural practices that increase carbon storage while benefiting producers and building ecosystem health.

Our conversations surfaced the following levers for restoring and activating agricultural lands as carbon sinks, across regions, operation size, and commodities:

- **Support expanded land access and tenure**, making conservation and carbon programs work for both land stewards and landowners through matching, apprenticeship, and land-sharing models, especially for those who work land they do not yet own.
- **Realign incentives to reward soil and ecosystem health** rather than work against it, better targeting conservation program funding, and building regional flexibility into contracts.
- **Develop and augment risk management structures** that allow for flexibility in soil and ecosystem health management, including crop insurance.
- **Expand markets and infrastructure**, easing the aggregation, processing, and marketing burdens that fall hardest on small and mid-sized producers, building demand for sustainably produced commodities.
- **Invest in local capacity and technical assistance**, prioritizing the community organizations land stewards rely on, enhancing the capacity of

technical service providers, and strengthening two-way learning between providers and producers.

- **Strengthen the science of carbon removal**, including investing more in research, development, and demonstration, and measurement, monitoring, reporting, and verification (MMRV) to address knowledge gaps in quantification, durability, and impacts, for both established and emerging pathways.
- **Promote management for broader ecosystem benefits**, building monitoring and payment structures that account for environmental and social values prioritized in land stewards' management decisions, where carbon is a co-benefit rather than the sole metric.

This report lays out what we heard across pathways, and shares how federal, State, and Tribal government, industry, local organizations, civil society, and land stewards can realize a sustainable agricultural system together.



GREEN HORIZON FARM, PHOTO BY COURTNEY FEE

Section One

Introduction

Introduction

The power of working lands

With over half of US land area devoted to agricultural production, American farmlands shape our environment at a scale few other sectors can match.

The health of our agricultural lands directly affects the supply of water, food, feed, and fiber, and in turn the resilience of our rural and urban communities. While farmland is no substitute for natural landscapes, it can also provide critical wildlife habitat and other ecosystem services.

Soil degradation has led to economic losses for farmers as well as a loss in ecosystem services. Already, in the Corn Belt, soil loss has reduced crop yields by 6%, estimated to cost \$2.8 billion in annual economic losses.⁴ A history of agricultural policies that prioritize large-scale production of low-diversity annual crops over soil health has resulted in an overall “debt” of ~130 gigatons of carbon in the top two meters of agricultural soils globally.⁵

This deficit accumulated over decades of excessive tillage, prolonged bare-soil periods, heavy agrochemical use, and other practices that break down organic matter faster than it can be rebuilt — compounded by the effects of climate change. This deficit can be reversed. Thankfully, many practices that build agricultural resilience build carbon as a co-benefit. And practices that build carbon — in soils, roots, and wood — also build agricultural resilience.⁶

Currently, croplands and grasslands in the US are a net carbon sink of 20-50 MtCO₂e per year, just 3-8% of the ~600 MtCO₂e in annual CO₂e emissions from the agriculture sector.⁷ Their untapped potential is much larger.



GOLDENROD AT NEW FOREST FARM, PHOTO BY COURTNEY FEE

SECTION ONE: INTRODUCTION

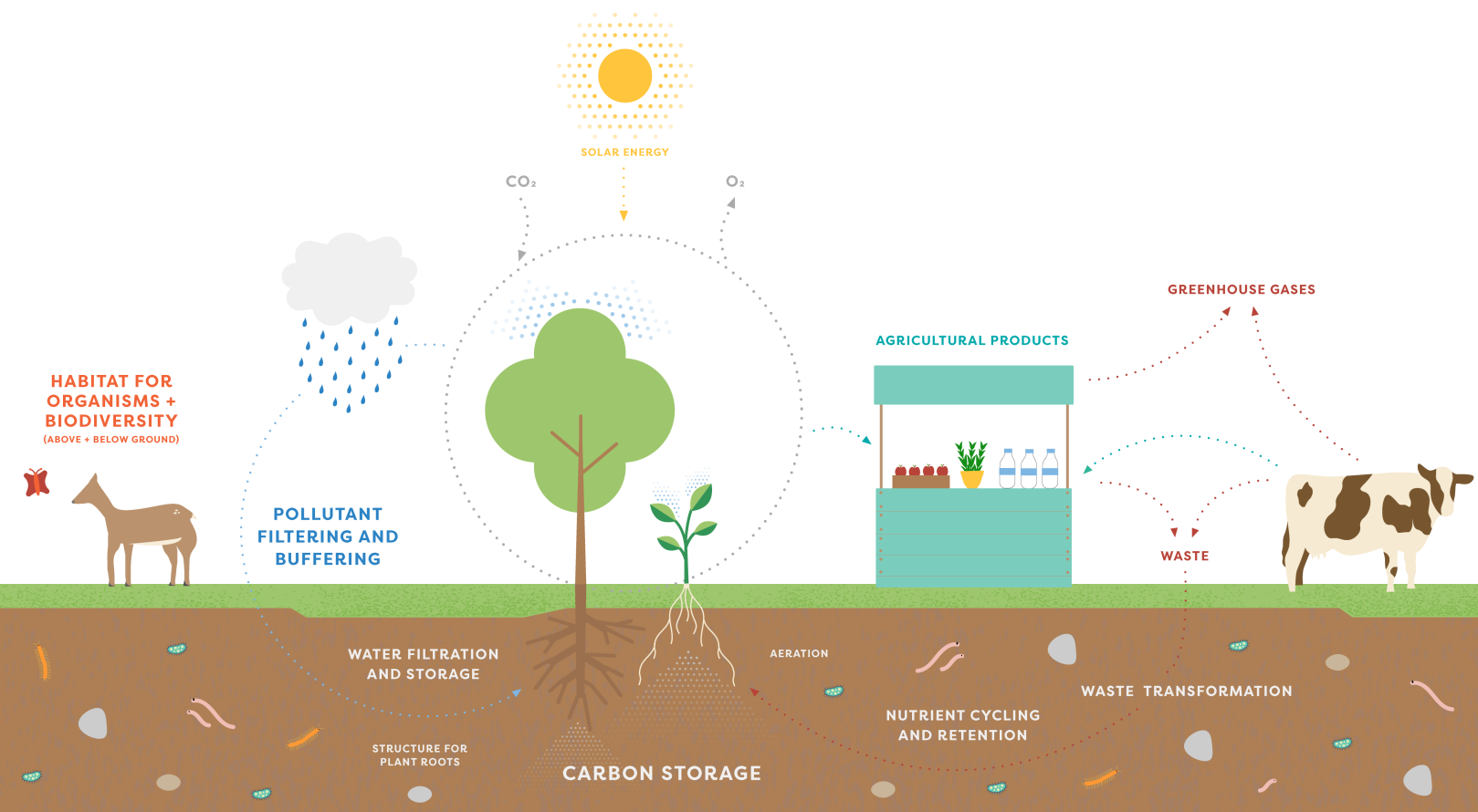
Agricultural lands can store much more carbon through improved land management, especially in places where unsustainable practices have degraded agricultural soils.

While currently a net emitter of greenhouse gas emissions, the American agricultural sector can meaningfully contribute to meeting CDR goals by changing the way we farm, integrating carbon removal into a broader transition towards healthier soils and sustainable land stewardship.

Through the widespread adoption of conservation practices, we can transition away from annual systems dominated by a few commodity crops, toward a more diverse, perennialized system. Newer pathways such as biochar and ERW may have the potential to not only scale carbon removal but also enhance soil health and fertility — though more research and demonstration is needed to confirm the ability to scale these pathways sustainably.

FIGURE 1

Healthy soil promotes multiple benefits



Carbon180's work on agriculture

Scaling agricultural carbon removal requires integrating scientific evidence with the lived experiences of the people who manage land every day.

In 2017, Carbon180 published *Leading with Soil*, a report that identified lack of technical assistance, mismatched financial incentives, and incomplete soil carbon research as key constraints for land stewards in the Rocky Mountain region. That work shaped our [Farm Bill platform](#) and the [Soil Carbon Moonshot](#), which called for an interdisciplinary interagency research program on soil carbon research and monitoring, reporting, and verification.

For this report, we expanded our engagement to build a more comprehensive vision of what scaling carbon removal would take across diverse agricultural lands and regions.

Over 2024 and 2025, Carbon180 partnered with local and regional organizations to convene listening sessions with over 200 land stewards across six US agricultural regions: the Southeast, Northeast, Midwest, Plains, Southwest, and Pacific Northwest, spanning operations from under 100 acres to over 3,000 acres, and including a diverse range of racial and ethnic backgrounds. Land stewards shared what works, what doesn't, and where support falls short in building soil carbon and health. We also interviewed scientists on scale, regional fit, and carbon and environmental benefits across practices and pathways.



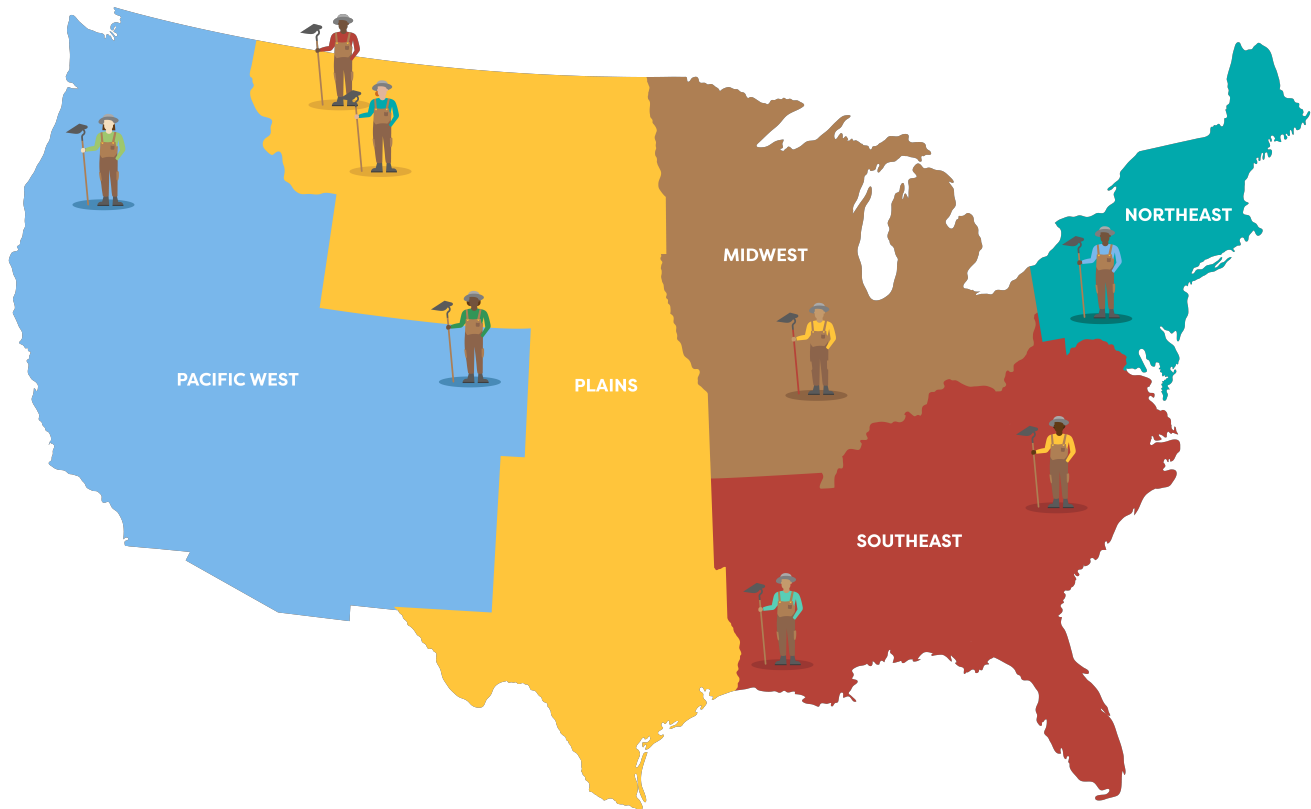
NIGHTFALL FARMS, PHOTO BY COURTNEY FEE

SECTION ONE: INTRODUCTION

This report shares what we heard and lays out a transformation that can restore the health of our agricultural lands, sustain farmer livelihoods and food security, optimize the function of soil and plant biomass as carbon sinks, and build agricultural resilience to climate change.

FIGURE 2

Map of farmer and rancher engagement listening sessions



SESSION PARTICIPANTS REPRESENT:



A VARIETY OF COMMODITIES
FROM SPECIALTY CROPS TO LIVESTOCK



MANAGERS OF LESS THAN 25 ACRES
TO OVER 3,000 ACRES OF PRIVATE,
COMMUNAL, AND TRIBAL LANDS



WHITE AND BIPOC
PRODUCERS

SEE THE [APPENDICES](#) FOR A FULL SUMMARY OF WHO WE ENGAGED

Section Two

Pathways

Pathways

Transforming agricultural lands into a net carbon sink requires re-imagining US agriculture.

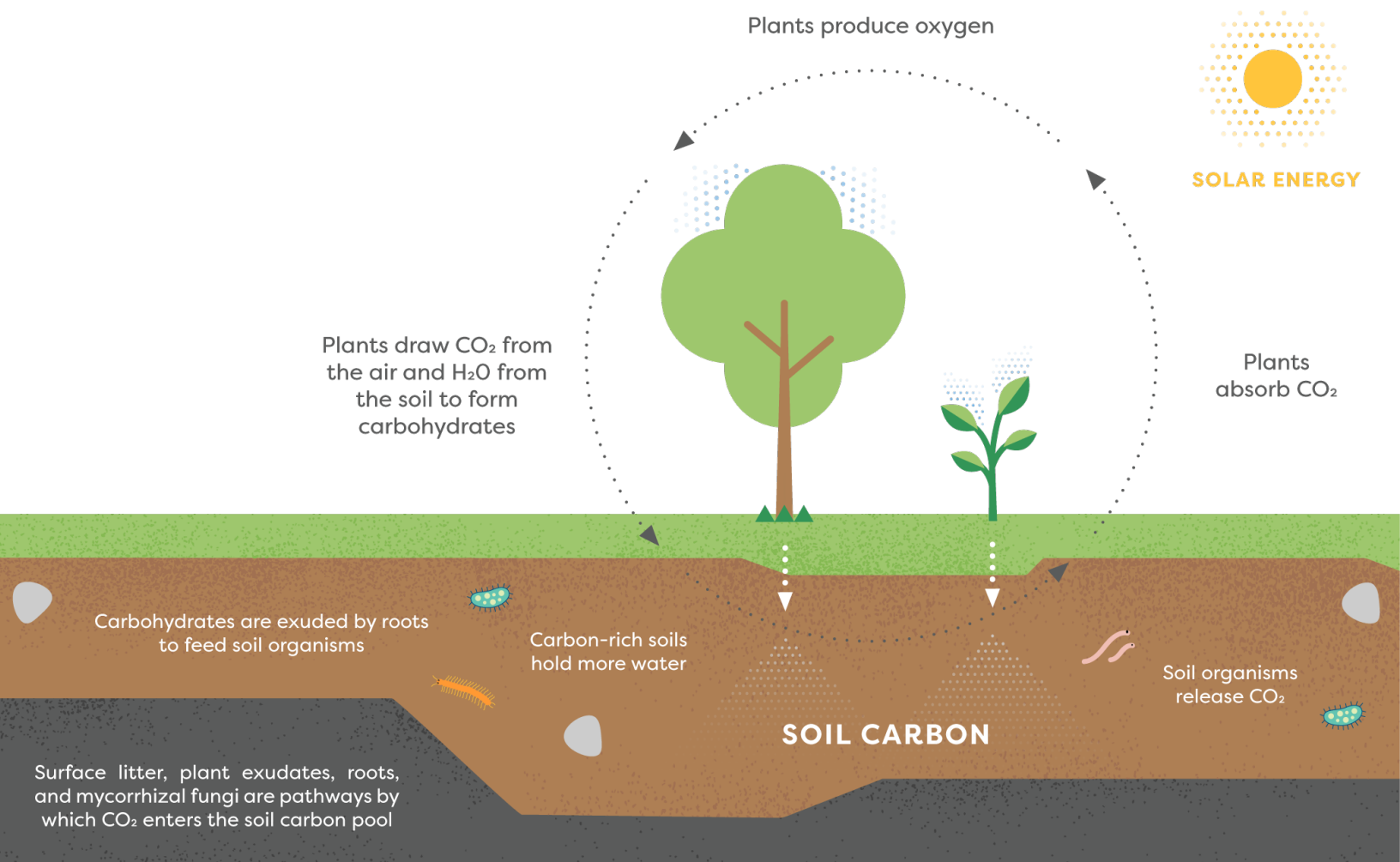
Below, we provide an overview of established and emerging carbon removal pathways to help identify the areas of greatest potential for enhancing carbon sinks while meeting land steward priorities.

Established pathways

The most established carbon removal pathways are practices that capture carbon in living systems. In agriculture, most are conservation practices that build carbon in soil and long-lived woody biomass, spanning agroforestry and sustainable agricultural land management.

FIGURE 3

Carbon removal through plants and soils



Building on work by the National Academies research agenda, an independent scientific working group convened by US Farmers & Ranchers in Action estimated that moderate adoption of established conservation practices across 175 million acres of agricultural lands in the US can remove 106 MtCO₂e per year over the next two to three decades. More aggressive adoption on 336 million acres could remove 204 MtCO₂e, assuming supportive economic incentives, technical guidance, and social support.⁸ Enhanced carbon sequestration would help offset up to a third of the 10% of total US greenhouse gas emissions contributed by agriculture. If pairing conservation practices with measures that cut emissions, US agriculture could become carbon neutral.

Table 1 summarizes carbon removal and net GHG impacts across established practices in the agricultural sector, which we have synthesized from the best available literature. We estimate both carbon removed and broader GHG impacts to ensure any claimed climate benefits are net-negative in emissions.

TABLE 1: INDICATIVE CARBON REMOVAL AND NET GREENHOUSE GAS IMPACTS OF CONSERVATION PRACTICES

PATHWAY	REPRESENTATIVE PRACTICE	CARBON SEQUESTRATION (tCO ₂ e/ha/yr)	AVOIDED GHG EMISSIONS (tCO ₂ e/ha/yr)	NET GHG MITIGATION (tCO ₂ e/ha/yr)
AGROFORESTRY	Alley cropping	4.95	0.46	5.41
	Conservation buffers	5.87	0.55	6.42
	Silvopasture	3.30	0.70	4.00
SUSTAINABLE CROPLAND MANAGEMENT	No-till	1.10	-0.11	0.99
	Reduced tillage	0.73	0.00	0.73
	Cover cropping: grass or mix	1.28	-0.05	1.23
	Legume tilled in	1.28	-1.00	0.29
	Cover tilled w/N	1.28	-4.79	-3.50
	Organic amendments Compost, C:N ~20	1.84	0.17	2.01
	Fertilizer C:N<10, tilled	1.84	-1.42	0.41
	Orchards and vineyards continuous living cover	3.67	0.00	3.67
	Cont. cover and compost	7.34	-0.24	7.10
SUSTAINABLE GRAZING MANAGEMENT	Improved grazing and rangeland mgmt*	0.26	0.37	0.62

* Improved grazing management is shown here for completeness on estimates but treated conservatively, and excluded from the CAST report estimate as its sequestration evidence is contested, revisited among emerging pathways.

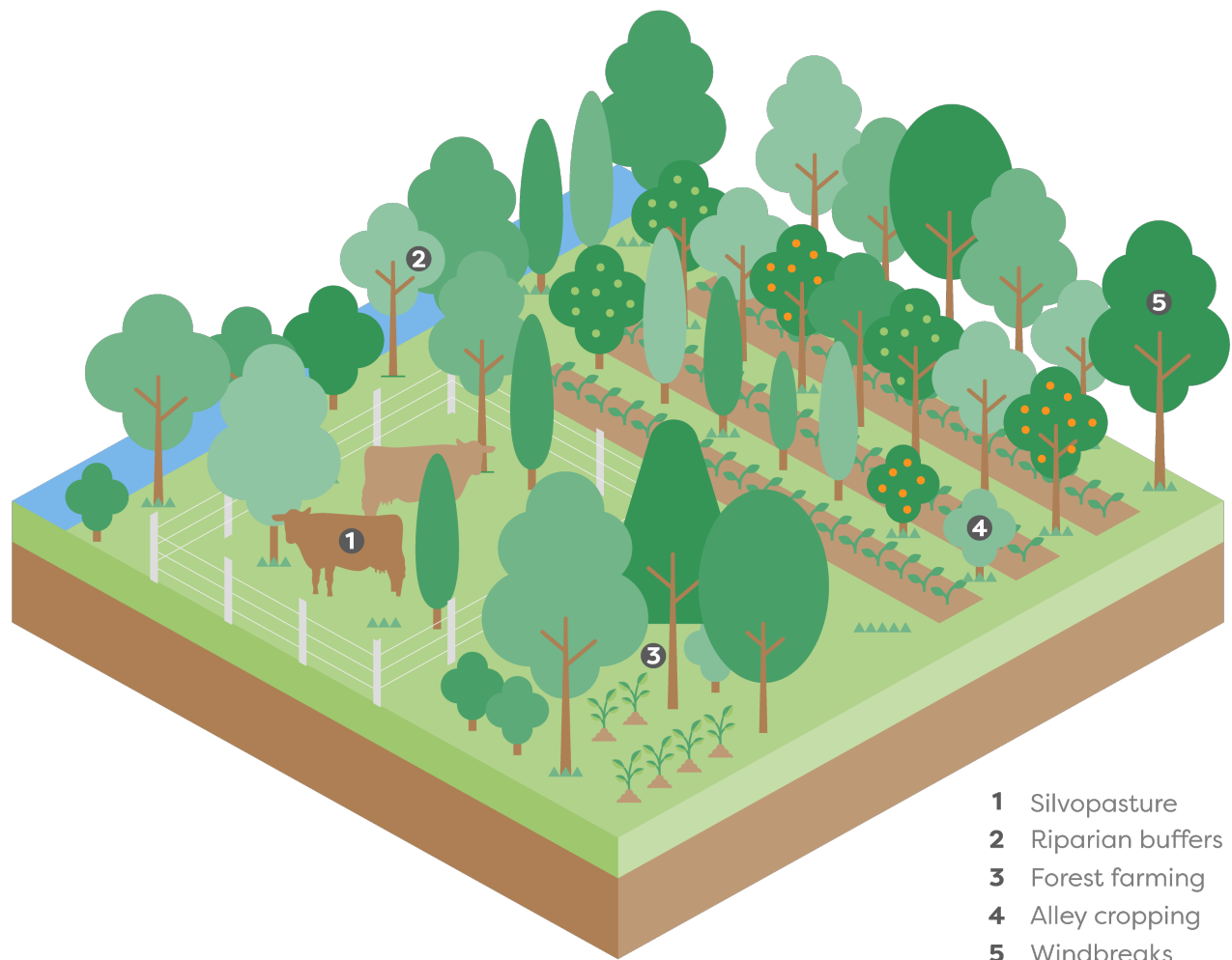
Note: These estimates draw from the COMET Farm model estimates for annual carbon sequestration (soil and, in the case of agroforestry, woody biomass) from various NRCS conservation practices⁹ and a global meta-analysis comparing soil organic carbon stocks with and without various practices and systems,¹⁰ and other sources detailed in Appendix Sources for carbon sequestration and GHG impact estimates.

Agroforestry

Among pathways, **agroforestry** offers the highest carbon removal potential per acre, given its substantial carbon storage in both long-lived woody biomass and soils.

FIGURE 4

Agroforestry



Five states in particular — Illinois, Indiana, Iowa, Michigan, and Wisconsin — are ripe with potential for agroforestry to improve on-farm resilience, restore soil health, and fortify rural agricultural economies. They collectively represent nearly 100 million acres of productive US farmland, drawing billions of dollars to rural agricultural economies.

To better understand the needs and priorities of agroforesters, in 2025 the Carbon180 team visited Upper Midwest farmers who champion agroforestry on their landscapes and demonstrate the power of diversified agriculture, particularly on marginal land.

Their stories featured in these [agroforestry case studies](#) illuminate the unique motivations, challenges, and creativity in implementing agroforestry, providing invaluable models for other farmers interested in transitioning. They also share what's still needed from policymakers, service providers, and researchers to make agroforestry systems thrive at scale.

Sustainable Cropland Management

Sustainable cropland management, which integrates organic amendments, biochar, continuous living cover, diversified crop rotations, perennials, and reduced tillage can also draw down meaningful carbon, primarily through soils.

That said, soil carbon levels reach a saturation point, so annual carbon removal rates are not perpetual. A lapse in management or exposure to extreme weather can reverse gains. Continued stewardship is critical to ensure the durability of carbon storage, based on the following principles, building on the Natural Resource Conservation Service's soil health management principles:¹¹

- **Minimize soil disturbance:** Reducing disturbance from physical, chemical, and biological soil disturbance (e.g., inappropriate use of nutrients and pesticides, over-irrigation, and overgrazing) mitigates soil carbon loss.
- **Maximize soil cover:** Crop residue and other organic materials such as mulch and compost, when left on the soil surface, provides a protective barrier for soil and associated soil carbon.
- **Maximize living roots in the ground:** Living roots build stable soil carbon far more efficiently than crop residue left on the surface. Deeper, longer-lived roots deposit carbon lower in the soil profile, where it is better protected from disturbance.
- **Stack practices:** While individual management practices can remove or protect soil carbon, stacking practices (e.g., cover cropping and nitrogen management)¹² and adopting integrated suites of practices (e.g., agroforestry) yield greater and more stable carbon storage benefits over time.

Soil organic carbon (SOC) is held in two main forms. Particulate organic matter, most abundant near the surface, stores soil organic carbon for years to decades, where decomposing plant material feeds soil life and cycles back out within a few seasons. Mineral-associated organic matter makes up a larger share of soil organic carbon deeper in the soil, providing a longer-lasting pool where carbon can persist for decades to centuries.¹³

Together, this makes a strong case for moving away from annual systems dominated by a few commodity crops, toward more diverse, perennial systems that build carbon both above and below ground. Transitioning from low-diversity annual rotations toward regenerative, permaculture systems involves gradually adding multiple carbon-sequestering practices over several years.

That said, there is no one-size-fits-all prescription. Different producers may take different roads toward more diverse, perennialized systems: some may selectively integrate practices into parts of their operations, while others may make a fuller transition. In addition, different approaches to diversification and perennialization are needed for different climates, soils, and bioregions.

The role of nature-based solutions in carbon removal

All carbon removal pathways share the purpose of removing legacy carbon dioxide from the atmosphere to mitigate climate change. However, we must differentiate the role of nature-based from technological solutions in addressing **two distinct carbon debts** that contribute to the climate crisis:

1. Land use change and unsustainable management practices have disrupted the fast, **biogenic carbon cycle (carbon produced by living organisms)** that moves carbon through plants and soils.
2. On the other hand, extraction and combustion of fossil fuels has disrupted the slow, **geologic carbon cycle** — carbon locked underground over millions of years.

Following a framework of equivalence based on sector and the carbon cycle disrupted: **Biogenic pathways**, including those that store carbon in living biomass and soils, as well as those that convert living mass to more durable forms (such as biochar), **are best positioned to restore biogenic carbon debts**, rather than address the combined carbon debt derived from fossil fuels.¹⁴

A phased, full-spectrum approach is critical in preventing climate tipping points in the short term and maintaining long-term climate stability — deploying biogenic pathways now while phasing out fossil fuels and exploring the potential costs and benefits of technology-based pathways.^{15,16}

- **Nature-based pathways** in the agricultural sector are ready, affordable, and grounded in a long history of existing practices and landscapes.
- **Technology-based pathways** vary considerably in readiness, current scale, cost, infrastructure needs, and durability — but have the potential to lock carbon away for centuries to millennia.

Table 2 profiles each pathway in more detail: where carbon is stored, how durable that storage is, ecosystem benefits, and environmental and social risks. Land stewards should determine suitability of practices based on local ecology and community needs.

TABLE 2: OVERVIEW OF CONSERVATION PRACTICES CORRESPONDING TO ESTABLISHED CARBON REMOVAL PATHWAYS

PATHWAY	REPRESENTATIVE PRACTICE	CARBON STORAGE POOL	MATURITY & PERMANENCE	ECOSYSTEM BENEFITS	ENVIRONMENTAL AND SOCIAL RISKS
AGROFORESTRY	Alley cropping; silvopasture; windbreaks; riparian forest buffers; forest farming	Soil organic carbon, aboveground woody biomass	Mineral-associated soil organic carbon and woody biomass are the most durable, longest-accruing pool; particulate soil carbon easily reversible	Soil health; erosion and flood control; nutrient cycling; water quality/retention; biodiversity/wildlife habitat; enhanced microclimate; can increase forage and yields	- Plantings in ecologically inappropriate areas can introduce pests and compete with native species - Financial risk for land stewards, esp. in cases where trees compete with crops for light, water, and nutrients, cutting yields
SUSTAINABLE CROPLAND MANAGEMENT	Cover cropping; no-till/low-till; shift from annuals to perennials; diversified rotations; organic amendments; residue retention; orchard/vineyard living cover; integrated crop-livestock systems	Soil organic carbon	Reversible if practices lapse; durability of practices such as no-till contested when soils sampled to depth; risk mitigated by combining conservation tillage with continuous living roots	Soil health; erosion and flooding control; nutrient cycling; water quality/retention; natural weed suppression; can increase forage and yields	- Can lead to lower yields - Gains reverse fast if tillage or bare fallow returns - Certain cover crops can raise N₂O emissions - Potential reliance on herbicides - Financial risk for land stewards

Managing for carbon as one of many benefits

The carbon removal field's focus on carbon removal, often at timescales on the order of centuries to millennia, sits in tension with the realities of farming and producer priorities.¹⁷

Carbon removal is not the primary benefit that land stewards seek in managing agricultural lands. Land stewards tend to be more interested in tangible benefits such as soil health, steadier yields, lower input costs, and resilience to drought and floods. To build land stewards' confidence in carbon-sequestering practices, it helps to frame adoption of new practices around familiar signifiers of prosperity, positioning carbon as a co-benefit, one that can be monetized in certain cases.

While many carbon-sequestering practices enhance these other benefits,¹⁸ there are cases where narrowly managing for carbon can harm other indicators of ecosystem health. For example, silvopasture established with a single fast-growing timber species rather than diverse native species can lead to biodiversity loss or water stress. It is therefore key to manage for carbon as part of a wider set of ecological outcomes, not ahead of them. Suitability of carbon removal

pathways varies based on local environment and land steward values. Scaling carbon removal durably and responsibly requires evaluating practices through a holistic lens across economic, environmental, and social values.

New horizons in organic agriculture

Organic agriculture is an integrated system of practices that can be applied across agroforestry, cropland, and grazing pathways, based on the principle of cycling nutrients and resources on-farm rather than importing them.

Associated practices such as composting, cover crops and integrated crop-livestock production build SOC, while avoiding synthetic inputs and conservation tillage reduce soil disturbance, preventing release of carbon.²⁹ More research is needed to assess and realize the potential of organic agriculture for carbon removal and food security, including on:

- Integrated soil health, SOC, and yield resilience strategies tailored to all major agro-ecoregions across the US.
- Impacts of organic agriculture on soil inorganic carbon, and identification of practices to conserve SIC while building SOC and improving dryland soil health and fertility.
- Crop-livestock integrated organic systems and other strategies to maximize on-farm cycling of organic carbon and crop nutrients and reduce the need for off-farm inputs.
- Diversified perennial and perennial-annual integrated systems to provide a wider range of nourishing foods than the current US corn-soy-wheat-livestock agri-food culture.
- Recycling, processing, and utilization of organic residues to replenish SOC and fertility.
- Cultivar and animal breed development for organic systems.
- Organic management of pests, weeds, and diseases.
- Shifts in infrastructure, markets, and government programming needed to unlock widespread adoption of regenerative organic agriculture



AGROFORESTRY SYSTEM AT RED FERN FARM, IMAGE BY COURTNEY FEE

Emerging pathways

The estimates above leave out a set of emerging pathways where field data remain sparse. More research, development, and demonstration is needed to monitor carbon, broader GHG and environmental and social impacts. Because these approaches are excluded from current sequestration estimates, the true removal potential of US agricultural lands is higher than the headline CAST report figures suggest. More independent field evidence and refinement of MMRV are needed to confirm the carbon and broader risks and impacts of pathways outlined in **Table 3**.

Within the realm of **nature-based pathways**, there are opportunities to enhance the carbon removal potential of established practices with newer science. More research is needed on expanding sustainable cropland management practices to include crop varieties with enhanced root phenotypes (i.e., larger, deeper root systems) and perennial grains.¹⁹

Improved grazing management can rebuild soil carbon across a large land base, but sequestration rates are modest and the science remains debated, requiring stronger evidence to confirm net greenhouse gas benefits. In addition, further research is needed to examine the impacts of management practices on soil inorganic carbon, to ensure supported pathways enhance total carbon (both organic and inorganic), not just soil organic carbon.

Other emerging pathways use agricultural land and biomass as an entry point for carbon removal but store carbon through physical or geochemical means rather than in living plants and soils.

Biomass carbon removal and storage (BiCRS) uses plants to draw down atmospheric carbon dioxide, then converts or contains biomass in deep geologic formations or long-lived products. **Enhanced rock weathering** spreads crushed silicate rock on fields, where it dissolves and converts carbon dioxide into dissolved bicarbonate that is then transported to the ocean. Another approach to accelerate silicate weathering, **microbial carbon mineralization**, uses microbial inoculants to accelerate weathering, converting carbon dioxide into carbonate minerals that accumulate in the soil as inorganic carbon.

These emerging pathways offer longer-lived storage than conventional pathways in the agricultural sector, but are early-stage and require more research and demonstration to assess their full environmental and social risks and impacts, potential to mitigate risks — and to confirm their viability as carbon removal pathways.

As our society grapples with the triple crisis of climate change, biodiversity loss, and inequality, it is critical to ensure that any investment in emerging carbon removal pathways is done in ways that benefit the communities and ecosystems where it takes place, including centering land stewards and communities in the design and implementation of supporting policies.

FIGURE 5

Emerging pathways

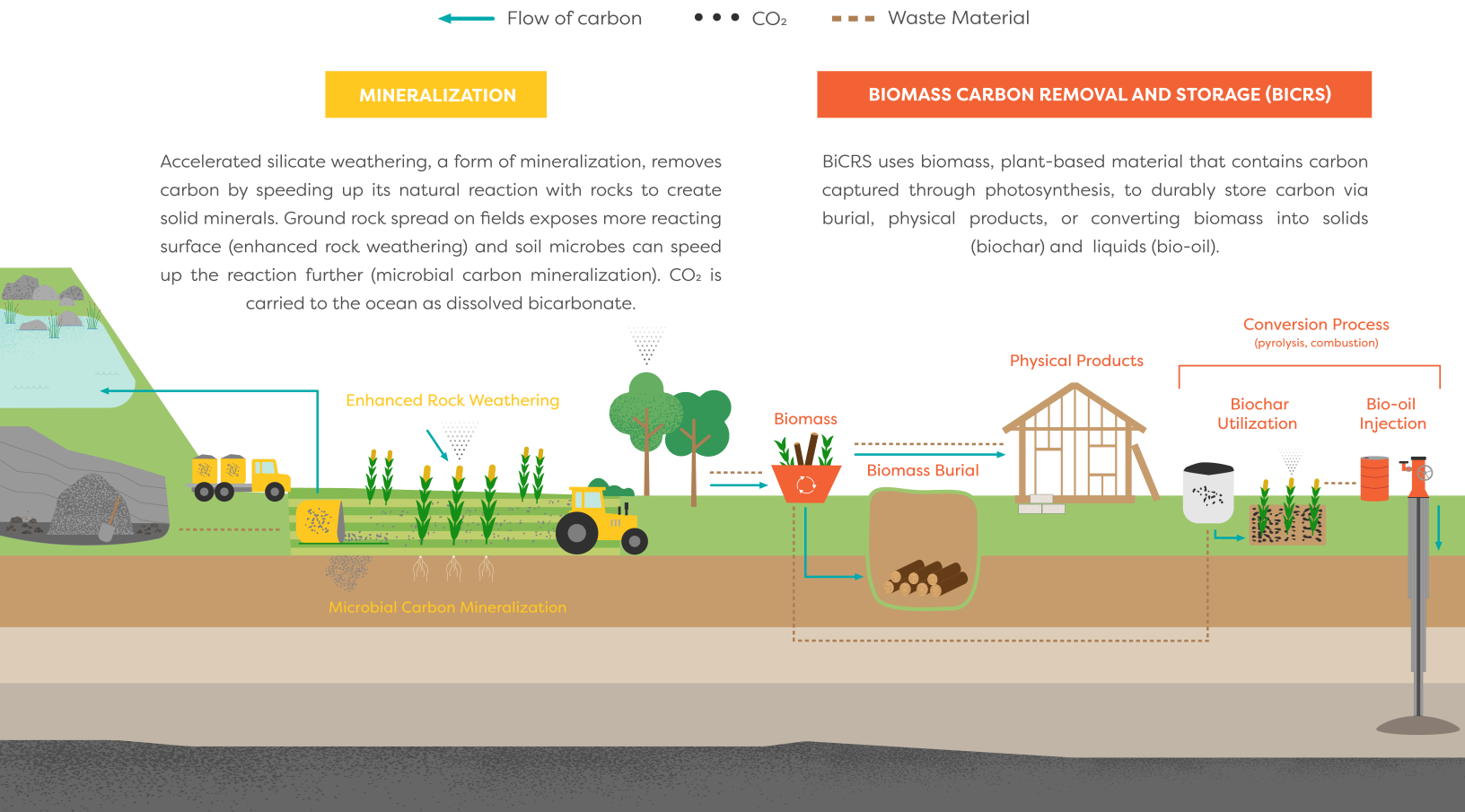


TABLE 3: EMERGING AGRICULTURAL CARBON REMOVAL PATHWAYS

PATHWAY	REPRESENTATIVE PRACTICE	CARBON STORAGE POOL	MATURITY & PERMANENCE	ECOSYSTEM BENEFITS	ENVIRONMENTAL AND SOCIAL RISKS
SUSTAINABLE GRAZING MANAGEMENT	Improved grazing; adaptive multi-paddock grazing; rangeland restoration; compost application	Soil organic carbon	Modest per acre in semi-arid climates, may be higher in wetter ones; very large land base; reversible; scientifically contested ²¹	• May add soil organic matter²² • Supports biodiversity, nutrient cycling, forage yield • Distributes manure more evenly • Can protect water quality	• Gains depend on stocking rate; esp. drylands²³ • Overgrazing causes compaction, runoff, erosion, eutrophication • Enteric methane emissions • More infrastructure required than continuous grazing²⁴ • Tenure and economic uncertainty for land stewards
BICRS – BIOCHAR	Pyrolysis of biomass (crop residues, brush, woody biomass removed to reduce wildfire risks) into stable char; char applied to soil	Pyrogenic ('black') carbon in soil	Early commercial – most mature emerging route; durable for decades to centuries; ²⁵ benefits depend on end-use and application	• Lime and fertilizer cost savings²⁶ • Enhanced water and nutrient retention²⁷ • Buffers pH • Immobilizes heavy metals & organic pollutants²⁸	• Feedstock contamination risk²⁹ (polycyclic aromatic hydrocarbons, heavy metals) • Residue harvest competes with soil retention³⁰ • Competes with alternative uses for feedstock • Tenure and economic uncertainty for land stewards
BICRS – BIOMASS BURIAL	Burial of woody or crop-residue biomass in engineered, oxygen-free pits or vaults	Physically preserved plant biomass carbon underground	Pilot stage; durable if anaerobic burial conditions maintained ³¹	• Uses residue that could pose fire hazard³² • Can pair with revegetation work • Can use degraded sites, supporting site remediation³³	• Deep excavation disturbs soil, habitat³⁴ • Methane generation if storage conditions are not maintained³⁵ • Residue harvest competes with soil retention • Competes with alternative uses for feedstock³⁶ • Potential long-term liability for host community • Tenure and economic uncertainty for land stewards
BICRS – BIO-OIL / BIO-SLURRY INJECTION	Conversion of biomass into stable bio-oil; oil injected into deep geologic formations	Geologic storage of biomass-derived carbon	Early, few projects; ³⁷ likely durable if carbon stays contained ³⁸	• Can reuse abandoned oil/gas wells • Can use biomass from wildfire management	• Groundwater leakage & well corrosion risks³⁹ • Limited safety data⁴⁰ • Competes with alternative uses for feedstock • Potential long-term liability for host community • Tenure and economic uncertainty for land stewards
ENHANCED ROCK WEATHERING	Spreading of finely crushed silicate rock (e.g., basalt) on cropland	Dissolved inorganic carbon carried by water to ocean; some soil carbonate	Field-scale verification an area of active research; ⁴¹ durable once carbon becomes bicarbonate	• Doubles as soil pH amendment⁴² • Potential for increased yields⁴³	• Nickel/heavy-metal risk⁴⁴ • Community impacts from expanded gravel pits and quarries with heavy traffic • Tenure and economic uncertainty for farmers⁴⁵
MICROBIAL CARBON MINERALIZATION	Microbial inoculants applied to stabilize soil carbon	Soil inorganic carbon	Pre-commercial; no defensible field evidence. Permanence unproven ⁴⁶	• Enhanced soil structure, nutrient cycling • Reduced need for fertilizers	• Introduced microbes could disrupt native soil communities⁴⁷ • Biosafety concerns in cases using engineered organisms • Tenure and economic uncertainty for farmers

Section Three

Barriers & Potential Solutions

Barriers & Potential Solutions

Adoption of practices to enhance soil health and carbon storage remains low.

According to the most recent USDA Census of Agriculture, only 28% of US farms use no- or reduced-till. Just 8% employ cover crops. Under 2% have implemented an agroforestry practice. While adoption of conservation practices on organic farms is higher,⁴⁸ only 1% of US farms are USDA certified organic. These figures reflect not simply a lack of awareness or demonstrated benefit, but a set of structural conditions that hinder land stewards from acting on what they know.

Unlocking greater adoption of carbon-sequestering practices will depend on a diversity of land stewards. Of the 1.9 million farming operations in the US, most are small family farms. Yet farms of 5,000 acres or more account for 42% of all agricultural acreage.

Larger farms have more resources to scale carbon removal practices. Small and mid-size farms are often interested but face barriers in adopting diversified, carbon-sequestering practices. Federal conservation programs have historically reached larger operations more readily, while smaller operations have least access to program support. Closing this gap in access to resources is critical for expanding adoption of conservation practices to a transformational scale, while ensuring the transition also benefits underserved and disadvantaged land stewards.

“If you want to regenerate soils, look at the ecosystems that generated that soil in the first place. These are virtually all perennial systems, grasslands.”

— Dr. Tim Crews, Chief Scientist and Director, The Land Institute

A shifting political landscape

Over the past two decades, interest in soil carbon sequestration has expanded across the public and private sectors, reflected in increased action in voluntary carbon markets, net-zero pledges, and bipartisan action on climate-smart agriculture. At the federal level, bills such as the Agriculture Resilience Act and the Climate Stewardship Act propose different financing paths to support widespread adoption of climate-smart practices.

In 2021-2024, the US Department of Agriculture (USDA) increased investment in conservation programs and soil carbon measurement, monitoring, reporting, and verification (MMRV) networks. However, since 2025, many of these programs have been canceled, rescinded, or halted, and climate objectives have

been removed. Federal interest in soil health and conservation management has persisted, including a set-aside of \$700 million within existing EQIP and CSP funding for regenerative agriculture practices. However, USDA staffing reductions and agency reorganization have greatly compromised the quality and reach of federal support. Land stewards remain interested in soil health and conservation programs but need more support to act.

“It’s so exciting to start a windbreak practice and to see how functional it will be on the landscape. It’s harder to deal with the trees when they die and need to be replanted or renovated. There needs to be support and a plan for maintenance from the beginning.”

— Dr. Lord Ameyaw, Assistant Professor,
University of Nebraska-Lincoln

Carbon180’s listening sessions and interviews with land stewards, scientists, and technical assistance providers consistently surfaced five enabling conditions for restoring the health of our agricultural lands and activating them as carbon sinks — across regions, size of operation, and commodities.

These span land access and tenure, market and infrastructure access, incentives and risk management, technical assistance and local capacity-building, and monitoring, research, and development. Below we detail barriers and potential solutions across each enabling condition, drawing on the perspectives shared during listening sessions and interviews.



We use this icon throughout this section to denote listening session perspectives.



Land access and tenure

Barriers

Tenure insecurity. Soil health practices are long-term investments, yet a large share of producers have no confidence they will still be on the land to realize benefits. In the US, 39% of farmland is rented or leased.⁴⁹ Many of these practices take several years or more to pay off. Even where a tenant builds soil carbon, those gains can be reversed once the lease ends and practices lapse.

Mismatch between contract terms and conservation practices. Land stewards renting from private landowners, federal agencies (Bureau of Land Management, Bureau of Indian Affairs, and the Forest Service), Tribal governments, and land trusts face different requirements and lease lengths. Even on federal lands, local offices interpret contract terms inconsistently. Renters must maintain compliance to preserve their current lease, but compliance does not guarantee renewal. Contract terms often do not support adoption of conservation practices, resulting in weak alignment between landowner and stewards' priorities. This uncertainty discourages upfront investment in infrastructure needed for conservation practices (e.g., no-till drills, fencing for regenerative grazing, and trees).

Unequal land access. Land access problems run deepest for producers historically excluded from land ownership. These patterns are rooted in the forced relocation of Indigenous people, the land dispossession experienced by Black farmers following emancipation, and decades of discriminatory lending and program administration.⁵⁰ This history continues to shape who has access to land, including through disparities in land and wealth, collateral for purchasing land, and capital to invest in conservation practices.

These patterns are visible today: 97% of farmers are white.⁵¹ Tribal land stewards face unique barriers to federal conservation programs. When non-Tribal stewards have already enrolled the maximum acreage in the Conservation Reserve Program, Tribal stewards can be locked out entirely. Many Tribal stewards also described difficulty navigating Bureau of Indian Affairs (BIA) and Tribal government approval processes for conservation contracts, even for practices on their own ranches. Off Tribal land, stewards often rely on personal funding; without financial support (as small as micro-grants), they struggle to access land for independent operations. Even after land is secured, limited

access to capital makes upfront investments required for conservation practices prohibitive.

Rising land prices, urban and residential development pressures, and market consolidation have worsened tenure insecurity in recent decades, affecting a growing share of beginning and mid-career farmers regardless of background. While young land stewards are interested in soil health practices, land is hard to come by unless passed down across generations.

“It takes time to build up carbon. What happens when a farmer gets kicked off the land? We need to keep roots in the ground and farmers farming.”

— Dr. Aidee Guzman, Assistant Professor of Biology, Stanford University

Solutions

Land stewards and other experts we spoke with shared the following solutions for strengthening tenure security as an enabling condition:

- **Matching programs** that pair values-aligned landowners with conservation-minded stewards, ensuring both parties share conservation goals from the outset.
- **Property tax incentives** for landowners who enroll agricultural land in eligible conservation programs, encouraging adoption of conservation practices.
- **Regional apprenticeship infrastructure** that pairs beginning farmers and ranchers with experienced, conservation-minded mentors, building skills and landowner relationships that support long-term land access and ownership.
- **Stronger USDA coordination** with federal (BLM, BIA), State, and Tribal landowners to build a shared understanding of conservation management, reducing landowner resistance to requests for conservation contracts, and strengthening conservation outcomes at the landscape level.

The **USDA Conservation Reserve Program (CRP) Transition Incentive Program** pairs values-aligned landowners with conservation-minded stewards. Upon CRP contract expiration, a land owner can receive two years of additional payments if transitioning their land to a beginning or veteran farmer/rancher who will preserve established conservation systems such as rotational grazing on the land.



Creative solutions on the ground

Seed farms: Older landowners plant trees and lease the land to younger stewards, who handle agroforestry maintenance and harvest — helping new farmers get started before they can buy their own land, and giving landowners capacity for practices they care about.

Multiparty leases: Landowners lease different tree species on the same plot to different stewards — e.g., maple to one for syrup, others for timber or nontimber forest products in the case of forest farming — sharing costs across multiple enterprises on the same land.

Path-to-ownership structures: Land held by a nonprofit, land trust, or cooperative lets beginning farmers build equity over time instead of leasing indefinitely.⁵²

Reduced mortgage interest rates facilitated by impact investors to support land purchases by BIPOC farmers.



ALLEY CROPPING WITH YOUNG OAK TREES AND CORN AT HUDSON FARM, IMAGE BY COURTNEY FEE



Incentives and risk management

Barriers

Incentives built for conventional production. US agricultural policy has long rewarded intensive production of a narrow set of commodity crops — corn, soy, wheat, cotton — on large, consolidated operations, backed by subsidies, crop insurance, and market systems. A land steward considering whether to add a cover crop or diversify into agroforestry is making that decision in an uphill environment where decades of policy have been organized around a different set of choices.

Penalization of early adopters and underresourced groups. Federal conservation programs — spanning the Environmental Quality Incentives Program (EQIP), Conservation Stewardship Program (CSP), Conservation Reserve Program (CRP), Regional Conservation Partnership Program (RCPP), and Agricultural Conservation Easement Program (ACEP) — operate at the margins of the dominant system of conventional production. Early adopters of conservation practices often find themselves ineligible for programs designed to recruit new adopters. Upfront costs for conservation practice infrastructure are significant, and cost-share programs reach only a fraction of interested producers, especially those from socially disadvantaged groups and smaller operations.

Insufficient support for maintenance of practices. Many conservation programs incentivize adoption of conservation practices, but do not provide support to maintain them after an initial conservation contract ends. CSP was intended to help sustain adoption of conservation practices, yet policy changes and inadequate funding have weakened support. Prior to 2018, roughly 60% of expiring CSP contracts were renewed annually, but that dropped to 20% following changes to CSP made in the 2018 Farm Bill, including a pause on renewals as part of a transition to a competitive renewal process.⁵³ Land stewards we spoke with noted that the program has proven complex, administratively burdensome, and chronically underfunded relative to demand, and that they wish it were easier to qualify for repeat funding to sustain stewardship. Under CRP, 80% of expired CRP land returns to production.⁵⁴ When the contract ends, the economics favor returning to production, even for producers who would prefer to maintain conservation outcomes.



Land stewards in Illinois noted that after a CRP contract ends, they often cannot afford to keep land out of production while paying operating costs such as property taxes on non-income-generating land.

Incompatible risk management structures. Risk management structures built around conventional production hold back land stewards who want to adopt conservation practices. During listening sessions, producers raised concerns of a lack of coherence in federal funding support. Certain federal programs (NRCS and FSA programs) support conservation practices, while others (crop insurance) can discourage them. More harmonization is needed across programs. For example, under an EQIP or CSP contract, producers work with local NRCS staff to implement a new management plan for improved soil health. EQIP funding can de-risk conservation practices to a degree; yet producers have still found it necessary to meet a new set of conservation practice requirements in order to apply for crop insurance, which banks require in order to approve an operating loan.

Even with recent updates extending risk management program eligibility to more conservation practices, program enrollment limits the land steward's ability to innovate on their land and adapt to local conditions. For example, crop insurance programs require the termination of cover crops by a specific date in each agricultural region, yet ideal termination dates vary across smaller geographies.

“We can educate. We can do science and research, and push the frontier. But none of that matters if these practices are inaccessible to producers.”

— Dr. Ashley Conway-Anderson,
Postdoctoral Research Associate,
University of Nebraska-Lincoln

Solutions

Land stewards and other experts we spoke with shared the following solutions for strengthening incentives and risk management as an enabling condition:

- **Reorient federal conservation program funding** toward practices that confer proven environmental benefits while building farm resilience. This includes expanding grant and cost-share payments from federal conservation programs to meet producer demand. Farm Bill reauthorization could be used to more actively reward conservation management, including as a critical form of risk mitigation. Support is particularly needed for land stewards from socially disadvantaged groups, smaller operations, and those who lack access to reliable commodity markets. Land stewards expressed a

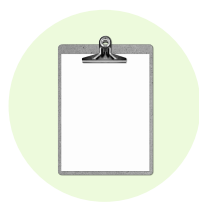
need for greater government investment in programs that support proactive conservation at a lower cost than CRP does, enabling land stewards to keep pace with conservation demands before land degrades.

- **Redesign of risk management structures** to accommodate — and ideally reward — conservation practices, with regional flexibility built into contracts and improved local data on how conservation practices affect yield in response to adverse weather. Longer-term plays include creative farm loan and insurance structures that recognize soil health as a risk-reducing asset rather than a liability (other options in Appendix, Alternative risk management and financing options). To support this, educate risk management program administrators on the links between soil health and resilience, so that they can better incorporate them into risk management and financial assistance programs. Enhancing education on the ecosystem benefits of these practices can inform program updates that support disaster risk resilience, stabilize food supply chains, and reduce costs for both land stewards and insurers.

Table 4 provides an overview of the federal conservation funding and risk management programs that serve as the largest levers for producer adoption of conservation practices.

TABLE 4: FEDERAL FUNDING AND RISK MANAGEMENT PROGRAMS RELEVANT FOR SCALING CONSERVATION PRACTICES

FEDERAL PROGRAM	ROLE	LIMITATIONS
ENVIRONMENTAL QUALITY INCENTIVES PROGRAM (EQIP)	• Supports initial adoption of conservation practices • Expand area under conservation management	• Consistently oversubscribed • Gap in regionally relevant technical assistance in a low-staffing scenario • Primarily short-term contracts (<3 years)
CONSERVATION STEWARDSHIP PROGRAM (CSP)	• Supports stacking additional conservation practices to enhance holistic conservation management • Rewards existing stewardship (e.g., by early adopters)	• Consistently oversubscribed • Gap in regionally relevant technical assistance in a low-staffing scenario • Short-term contracts (5 years), renewed via competitive process • Application process and ranking complex and opaque
CONSERVATION RESERVE PROGRAM (CRP)	• Supports conservation of degraded land through 10-15-year contracts • Can support longer-term soil health practices	• Currently oversubscribed • Gap in regionally relevant technical assistance in a low-staffing scenario • High rate of reversion back to cropland after expired contract • Requires land to be degraded prior to enrolling
RISK MANAGEMENT PROGRAMS (E.G., CROP/ DROUGHT INSURANCE)	• Buffers yield and revenue losses • Reduces downside risk during transition years when practice changes can temporarily lower yields • Often required for land stewards to get operating loans	• Misaligned with conservation management realities • Land stewards must choose between financial risk management and conservation practices



Technical assistance and local capacity building

Barriers

Limited producer awareness and access to relevant programs. Land stewards often struggle to find information on what federal, state, and private sector support programs are available to them. In Montana, land stewards shared that pre-COVID-19, they were able to secure help by going physically into the local NRCS office, noting that NRCS staff knew them individually and alerted them of new programs and opportunities.

With a shift toward more online support post-pandemic, land stewards noted it being much harder to know what programs are currently available. The low number of NRCS staff impacts how often they can be out in the field with producers. Local organizations are more adept at educating land stewards on regionally relevant management practices, but much more limited in reach.

“There are lots of right ways to implement silvopasture and there are definitely wrong ways, which can be daunting to producers.”

— Dr. Ashley Conway-Anderson,
Postdoctoral Research Associate,
University of Nebraska-Lincoln

Limited USDA capacity. NRCS, the primary federal vehicle for conservation technical assistance, operates through local offices with uneven staffing and expertise. While some producers noted NRCS support to be critically needed and valuable, other producers noted inconsistency of information provided by different NRCS offices across regions, heavy paperwork, prolonged contracting timelines, and lack of transparency in how contracts are awarded. Reductions in the federal workforce since 2025 have further thinned NRCS staff capacity. Land stewards who worked hard to secure NRCS contracts, only to have the funds frozen or rescinded, are less likely to re-apply.



Land stewards in Oregon and Illinois waited years between initial engagement with NRCS and receiving a signed contract allowing them to begin a practice.

Distrust among underserved groups. Most land stewards we spoke with described decent relationships with NRCS staff, but the quality of NRCS

support varies, and often falls short for underserved groups. A history of USDA discrimination, paired with the recent rollback of protections for socially disadvantaged producers⁵⁵ throughout USDA programs has compounded distrust among minority farmers, even if these set-asides remain intact in NRCS and FSA programs.



Black specialty crop farmers in Louisiana expressed distrust of NRCS, recounting multiple visits to NRCS offices simply to check in about a soil health test, and doubting whether the engagement was worth their time.

Need for local knowledge exchange. Land stewards overwhelmingly prefer to approach local individuals and community organizations before NRCS staff to learn about innovative management practices and troubleshooting day-to-day maintenance. NRCS, Extension, and formal research institution agents sometimes lack current, firsthand farming experience.



- A producer in Montana noted that Extension staff still educate on chemical inputs while omitting newer information on biological controls, which better support soil health.
- Land stewards in Oregon described the value of observing a practice's outcome on a neighbor's land before changing their own management.
- Producers in the Northeast noted the value of building community around implementation and the "exchange of wisdom" on specific practices.

Lack of nuanced management guidance. Most carbon-sequestering practices benefit from specialized technical assistance focused on appropriate plant species, management regimes, planting dates, fertilizer and soil amendment application rates, and practices for specific management goals and regions. Yet technical assistance programs are limited in providing such tailored guidance. For example, land stewards use the word "compost" to refer to mulch, manure, or other soil amendments, and NRCS language often fails to capture on-the-ground complexity. The carbon potential of practices such as no-till and cover crops has received research attention, but producers still need regionally appropriate practical information to adapt practices on-farm. Additionally, land stewards trained in conventional agriculture need guidance on tapering use of synthetic fertilizers, pesticides, and herbicides while maintaining yields; as conservation practices build soil organic matter, soils can become more fertile and require fewer synthetic inputs.

BIPOC Leadership in Agroforestry

BIPOC land stewards have practiced agroforestry for millennia, tapping into Traditional Ecological Knowledge, culturally significant foods, and community connection across generations. As agroforestry gains visibility in federal policy for its carbon, ecosystem, and operational benefits, it is essential to center BIPOC perspectives in policy development.

In 2024, Carbon180 convened a Steering Committee of BIPOC leaders in agroforestry across eight US regions to identify opportunities to educate policymakers on the support that USDA programs can provide agroforesters from underrepresented communities. A year of engagement revealed:

- The language NRCS uses in its practice standards often does not match the terms that BIPOC agroforesters use on the ground, leaving many practicing agroforestry uncounated and unsupported. The National Agroforestry Survey identifies only two percent of farms as implementing at least one agroforestry practice. NRCS technical staff need deeper fluency in the diversity of cultural and regional expressions of agroforestry to close this gap.
- Firsthand knowledge from BIPOC agroforestry communities remains siloed. Mentorship networks, including those led by Tribal women, have connected different agroforestry operations across regions and enabled land stewards to bring knowledge back to their own communities. However, without formal support infrastructure, that knowledge does not travel as well as it should.

Solutions

Land stewards and other experts we spoke with shared the following solutions for strengthening technical assistance and local capacity-building as an enabling condition:

- **Enhanced program visibility** through regional or local repositories collating information on federal, state, and private sector programs, eligibility requirements, and simultaneous enrollment options to help land stewards identify programs.
- **Greater NRCS capacity and reduced application burden** to ensure more responsive, accessible technical assistance across regions.
- **Investment in and formal partnerships with trusted local community organizations**, extending technical assistance on carbon and soil health programming beyond NRCS capacity, and ensuring programs reflect regionally appropriate management practices and are accessible by land stewards of all demographics.
- **Expanded funding for mentorship and farmer-to-farmer networks**

to support peer learning — identified as an especially promising lever for scaling agroforestry.



Land stewards pointed to the National Fire Protection Association's Firewise USA model, which supports community-led wildfire mitigation, as a model for federal agencies to enable community-led conservation efforts, where communities learn from each other and implement management regimes to reach collective conservation goals.

- **Two-way learning**, through two-way workshops in which NRCS and Extension staff share technical assistance program information while learning from producers about the day-to-day decisions shaped by conservation management — building trust and enabling on-the-ground adaptation. Pairing firsthand experience from field practitioners with academic research can also augment producer education on specialized management.
- **Regionally tailored decision support tools**, coupled with trusted education partners, to help land stewards plan for how a practice will impact their operation.
- **Specialized technical assistance** on managing carbon and tapering nitrogen inputs while maintaining yields (critical for mitigating N₂O and net GHG emissions), which may help build buy-in for carbon management among skeptical producers.



Market and infrastructure access

Barriers

Market consolidation and market deserts. Conservation practices often involve managing a diversified operation. Practices such as agroforestry, cover crops, perennial grains, and polyculture require land stewards to access markets for new products to ensure an economically viable enterprise. Decades of market and processing facility consolidation have concentrated buying power and limited options available to producers who want to diversify. Even where markets exist for new and alternative crops, land stewards face “market deserts,” with processing centers sometimes a four-hour round trip away. There is little incentive for companies to expand markets into new locations, creating barriers to adding crops such as perennial grains into an existing rotation.

Need for increased aggregation. Finding buyers, negotiating terms, and moving products to market all fall on the producer. A large operation can absorb this burden, but a small one often cannot. Cooperatives stood out across listening sessions as an essential support structure to help producers with aggregation, processing, and marketing of commodities, key for breaking into more durable commodity markets. Land stewards also identified “community hubs” as a model for connecting new agricultural products to existing local markets. However, access to these models is uneven and their reach remains limited without formal support infrastructure.

Insufficient sustainability premiums. Land stewards identified premium payments for sustainably produced commodities as a meaningful lever, compensating for the added time and labor, and tapping growing consumer interest in food quality and “food as medicine.” However, competing priorities prove difficult to reconcile: while land stewards want higher payments for sustainably grown goods, industry wants to keep prices low to maximize profits, and price conscious consumers prioritize affordability.

Inaccessibility of carbon markets and carbon-specific programs. Voluntary carbon markets have had real but limited success in motivating adoption of conservation practices. Many land stewards remain skeptical or unable to access them given high project development costs, and the tendency to place financial risk on producers without guaranteeing payment. Carbon markets are

not built to reliably reward the maintenance of carbon in agricultural systems, given additionality hurdles and uncertain demand. Compliance carbon markets have largely excluded soil carbon methodologies. What's more, a narrow focus on additional carbon storage can sideline other values critical for day-to-day soil health management.

The private sector has continued to incorporate offsets and insets into their sustainability strategies, leading to the growth of voluntary carbon markets and net-zero strategies for agricultural supply chains. Yet just 4% of farmers report participating in an industry-sponsored sustainability program compared to 57% participating in government programs, underscoring how much public sector support matters.



- A Colorado producer shared a fear that land stewards who implement carbon-sequestering practices with the hope of participating in carbon markets are penalized if they cannot measure a large enough change in soil carbon.
- Tribal producers underscored that the landowner (Tribal government or the Bureau of Indian Affairs), rather than land stewards, receive the carbon market payments for any carbon sequestration.

Solutions

Land stewards and other experts we spoke with shared the following solutions for strengthening market and infrastructure access as an enabling condition:

- **Strengthen support for cooperatives and community hubs**, using shared infrastructure and services to relieve producers from the burden of operations, processing, transportation, and marketing.



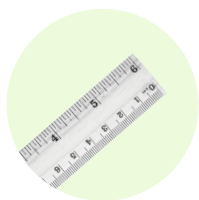
- Specialty crop growers in South Carolina highlighted a local foods program that handled transportation of goods to market while cutting out the middle man, increasing their net revenues.
- Black specialty crop growers in Louisiana valued co-ops that provide aggregation and marketing services, and resources for on-farm assistance to minority farmers.
- Tribal land stewards in Montana developed a co-op model where a local non-profit buys expensive shared equipment that individual operators "check out" for use.
- Land stewards can sell minimally or unprocessed products from trees grown in agroforestry systems to florists, basket weavers, and other artisans in a community hub.

- **Strengthen private and public sector procurement** of goods produced with conservation practices, through market premiums and sustainable certification programs. As a major agricultural procurer, the federal government has unique leverage to create demand-side incentives without passing costs to consumers.
- **Strengthen federal support for market infrastructure**, building producer interest in conservation practices by bolstering (a) co-ops, brands, and companies that market sustainably grown commodities, and (b) local processing centers.



- Programs such as Partnerships for Climate-Smart Commodities (PCSC) and the Local Food for Schools Cooperative Agreement were important federal levers of market support. They were terminated in 2025, leading to a gap in federal market support for conservation practices. Some PCSC projects have been able to secure support under the replacement program, Advancing Markets for Producers (AMP), which supports some forms of conservation and soil health practices.
- Land stewards in Colorado expressed interest in corporate buyers creating sustainability metrics to grade and determine which commodities qualify for a premium. Colorado's Saving Tomorrow's Agricultural Resources (STAR) program provides food buyers with an evaluation system for sustainable commodities.
- The Grazewell program at Country Natural Beef, a cooperative of family farmers, provides technical support to ranchers, requiring them to maintain soil health practices to sell beef at a premium.

- **Give conservation programs more flexibility** to pair conservation and production, instead of prohibiting land stewards from profiting from conservation areas on their operation. The Grassland Conservation Reserve Program provides precedent by allowing grazing and haying on CRP land as long as conservation outcomes are maintained. This model can be adapted to agroforestry systems and other cases involving increased crop rotations on farmland.
- **Tempered investment in carbon markets** as a niche complement to commodity market solutions, not a substitute. Long-term stewardship will require durable sources of demand beyond voluntary carbon markets, recognizing that agricultural carbon management depends on continuous stewardship rather than one-time gains in additional carbon storage. Where carbon markets are pursued for agriculture, strengthen the integrity of carbon methodologies and enhance benefit-sharing, where compensation flows to the land steward who bears the management risk, not only to the landowner.



Monitoring, research, and development

Barriers

Existing MMRV is not fit for purpose. Soil health and carbon programs are split into outcome-based models (carbon market payments) and practice-based models (NRCS cost-share for specific practices). Neither is independently well suited to informing daily management or reliably unlocking payments for carbon and other environmental benefits over the medium to long term. Land stewards and scientists we spoke with called for monitoring that is more practice- and environment-specific, centered on outcomes land stewards care about.

Developing infrastructure for carbon claims. The lack of widespread, robust soil carbon MMRV limits the rigor and confidence in outcome-based financing programs, particularly on issues of additionality and durability. There is still no national system for measuring and modeling regional on-farm carbon sequestration. Standards for sampling, analysis, modeling, and data reporting remain fragmented.

More is needed to lower the cost of MMRV, and to pair soil carbon research with collaborative on-farm research to better understand the effects of management practices by region.⁵⁶ High per-project MMRV costs — often \$150–200 per farmer on top of practice-change costs⁵⁷ — are a real barrier to producer entry into voluntary carbon markets, particularly for small and mid-sized operations. Other mechanisms such as the 45Z tax credit fluctuate in their list of eligible practices and size of premium offered, such that land stewards feel like they are chasing a moving target.

“As fast as we can produce models that can predict what will happen in certain ecosystems, the ecosystem or climate changes. That instability will make it impossible to continue to base models on static risk assessments.”

— Karam Sheban, Research Manager,
Yale School of the Environment

Solutions

Land stewards and other experts we spoke with shared the following solutions:

- **Expand monitoring in practice-based programs**, so land stewards can confirm if their conservation practices are meeting environmental outcomes and their own operational goals, critical for informing long-term

maintenance.

- **Invest more in research, development**, and demonstration for soil carbon as well as emerging carbon removal pathways featuring biomass and geochemical processes. That includes carbon MMRV as well as evaluating environmental and social risks and impacts of each pathway.
- **Pool MMRV through aggregated and jurisdictional approaches**, enabling monitoring and verification across farms or an entire region to reduce producer costs, particularly for small and mid-sized operations.
- **Diversify non-carbon metrics in outcome-based programs**, spanning environmental, social, and economic indicators that give land stewards better data to inform their own management decisions. Making this data public at the county level would extend its value to the surrounding agricultural community.



Producers named soil moisture, biodiversity, pollinator abundance, and yield or production outcomes as critical metrics useful for management decisions. Experts cited a variety of biodiversity metrics tailored to a steward's specific goals: key fish species in streams near riparian buffers, the disappearance of problem weeds under cover cropping, the return of wildlife to rotationally grazed systems.

Others pointed to water quality, reduced soil erosion, below-ground microbial activity, water infiltration and drought resilience — along with community indicators like the share of a farmer's income tied to a given practice, or the average age of participating producers as a signal of generational engagement.

- **Increase certainty in outcome-based program requirements**, e.g., eligibility lists and premium structures, so that land stewards can better participate in programs, e.g., voluntary carbon markets.

Section Four

Vision

Vision

The United States has an opportunity to integrate carbon removal into a deeper, much needed transformation of the agricultural sector that restores soil and ecosystem health.

Across six regions, land stewards told us how they seek to manage for soil health, water quality, biodiversity, on-farm resilience, and other tangible benefits, often using the same practices that build carbon. Established practices in agroforestry and sustainable cropland management are critical for rebuilding carbon in degraded landscapes. The science and practice of other nature-based biogenic carbon removal approaches, such as grazing management, continue to evolve, as do emerging pathways that pair biomass and geochemical processes — approaches that hold promise but require continued research to substantiate carbon claims at scale.

The few programs that reward carbon removal on agricultural lands reach only a fraction of interested producers, and do not always respond well to land stewards' needs and priorities. Incentives for diversified conservation agriculture remain marginal compared to support for conventional monoculture systems.

Restoring the health of our agricultural lands and activating them as carbon sinks at scale will require the public and private sectors, civil society, and other actors to restructure support for agriculture and carbon removal — with land stewards at the center, and carbon as one of multiple benefits to manage for.

“Policy has created these issues, so it should be on policy to fix these structural problems.”

— Dr. Paige Stanley, Research Scientist,
Colorado State University

Drawing on the perspectives of land stewards, technical service providers, and scientists we spoke with, we call for coordinated action to advance the following:

- **Support long-term tenure**, making conservation and carbon programs work for both land stewards and landowners through matching, apprenticeship, and land-sharing models that strengthen the basis for conservation management, especially for those who work land they do not yet own.
- **Realign incentives to reward soil and ecosystem health** rather than work against it, better targeting conservation program funding, and building regional flexibility into contracts.

SECTION FOUR: VISION

- **Develop and augment risk management structures** that allow for flexibility in soil and ecosystem health management, including crop insurance.
- **Expand markets and infrastructure**, easing the aggregation, processing, and marketing burdens that fall hardest on small and mid-sized producers, building demand for sustainably produced commodities, and giving working-lands programs the flexibility to pair conservation with production.
- **Invest in trusted local capacity and technical assistance**, prioritizing the community organizations land stewards rely on, enhancing the capacity of technical service providers while reducing application burden, and strengthening two-way learning between providers and producers.
- **Strengthen the science of carbon removal**, including investing in research, development, and demonstration and MMRV to address knowledge gaps in quantification, durability, and impacts, for both established and emerging pathways.
- **Promote management for broader ecosystem benefits**, building monitoring and payment structures that account for environmental and social values prioritized in land stewards' management decisions, including where carbon is a co-benefit.

Key actors for bringing this vision to life include:

- **Land stewards.** Their on-the-ground experience should directly shape policy design and implementation. Farmers, ranchers, and other practitioners need low-burden channels — advisory councils, listening sessions, comment periods timed to the agricultural calendar — to connect with policymakers and federal agencies without pulling them away from their work.
- **Federal policymakers.** Federal policy remains organized around intensive production of a handful of commodities, and even popular conservation programs reach a fraction of interested producers. Beyond expanding options and funding, that means rebalancing commodity and conservation support to more proactively incentivize diversified agricultural systems that meet multiple environmental and operational goals, funding maintenance of practices beyond initial adoption, and using federal procurement to build demand for sustainably produced goods.

Our companion report, *Restoring Carbon for Healthy Agricultural Lands: A US Federal Policy Roadmap*, to be released in Q4 2026, provides in-depth federal policy recommendations.

- **Companies.** Industry’s engagement on carbon has centered on carbon markets, sustainable sourcing, and markets for sustainably grown goods. Companies can go further by directing profits to higher premiums and other producer incentives — and strengthening procurement of conservation-grown commodities. Where carbon markets are used, the private sector can improve methodology integrity and ensure payments reach land stewards.
- **Research institutions.** Knowledge gaps persist on implementing and quantifying carbon and other impacts across perennial systems, managed grazing, and pathways involving biomass and geochemical processes. Collaborative research is needed to evaluate and prove out emerging pathways, including on carbon MMRV and ensuring broader environmental and social risks and impacts are understood.
- **Local and regional organizations.** Non-profits are often the most trusted entities land stewards turn to. BIPOC organizations, many bearers of Traditional Ecological Knowledge, are best equipped to help their communities implement agroforestry, perennial systems, and other practices. Farmer-to-farmer networks and cooperatives are critical providers of technical and market access.
- **State, Tribal, and local governments.** Much closer to the land stewards they serve than the federal government, these governments understand regional priorities. They can design and implement policies that advance subnational and community goals while building carbon.
- **Financial institutions.** Most producers depend on loans for operating costs and insurance against losses. As evidence accumulates that soil health practices reduce operational risk, lenders and insurers can price that in directly through interest rate deductions, better terms, and products that treat healthy soil as a risk-reducing asset, not a liability.

Figure 6

A systems approach to restoring soil health and carbon on US agricultural lands



Agricultural lands can only become durable carbon sinks if our agricultural system serves the people managing them.

Only through shared commitment and action can we realize a truly sustainable agricultural system: one that centers soil and ecosystem health, repays the carbon debts accrued over generations of land use shaped by unsustainable incentives, and creates resilient agroecosystems that support production alongside thriving ecosystems and communities.

To join forces in advancing this vision, email land@carbon180.org.

Appendices



APPENDIX 1

Farmer and rancher listening sessions

We are grateful to have partnered with multiple land steward facing organizations across the US to engage farmers and ranchers in listening sessions to understand challenges they face and opportunities they seek out for support in building soil carbon. Our partners on this work include:

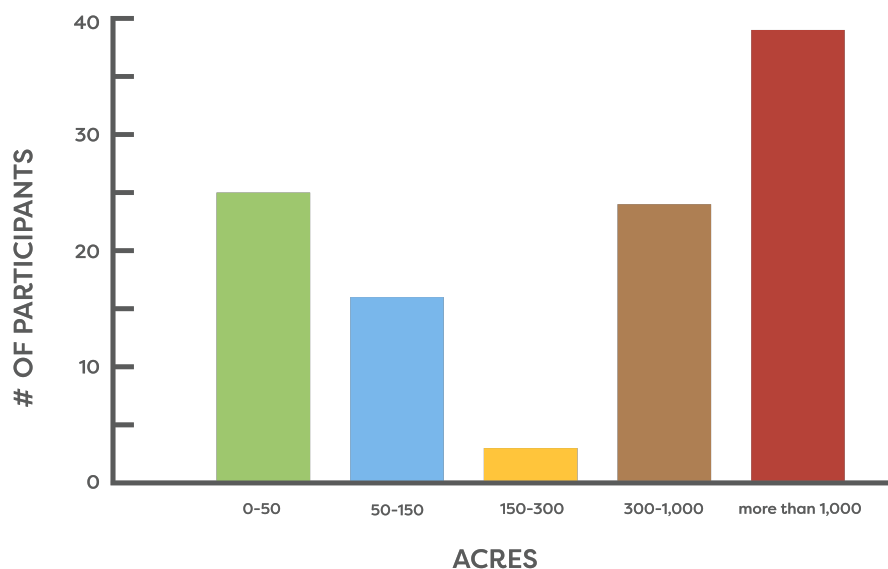
- Harvey Reed III
- Northern Plains Resource Council
- Pasa Sustainable Agriculture
- Piikani Lodge Health Institute
- Rural Voices for Conservation Coalition
- Savanna Institute
- Wallowa Resources

Our partners' participation reflects a shared interest in soil health and agricultural resilience. Responsibility for the findings and recommendations rests with Carbon180.

The land stewards we engaged had deep familiarity across conservation agriculture practices, including many producers who implement multiple practices on their land.

Figure 7

Agricultural land managed by listening session participants



Farmer and rancher listening sessions

Figure 8

Conservation practices implemented by listening session participants

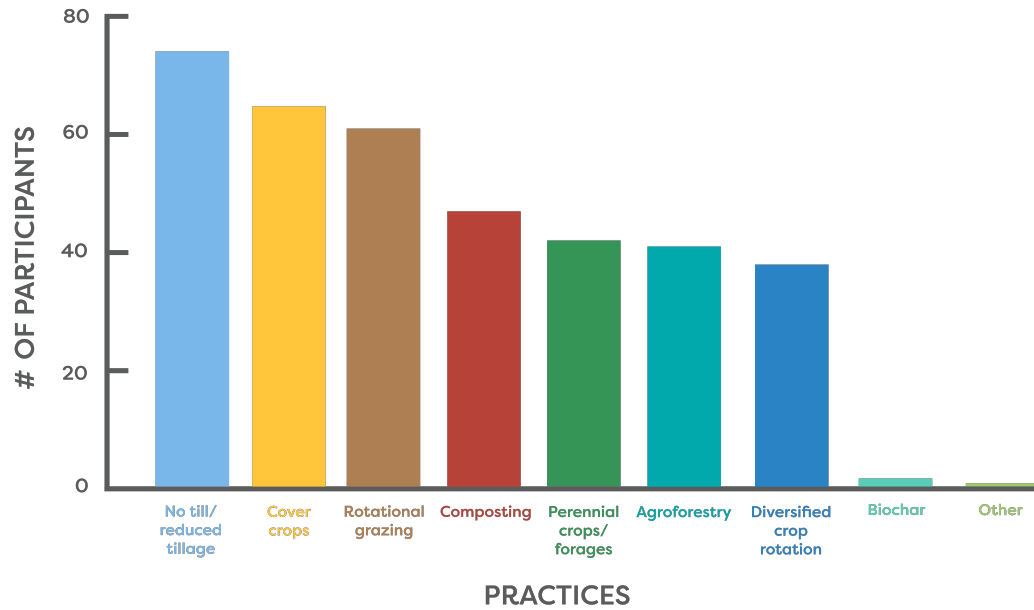
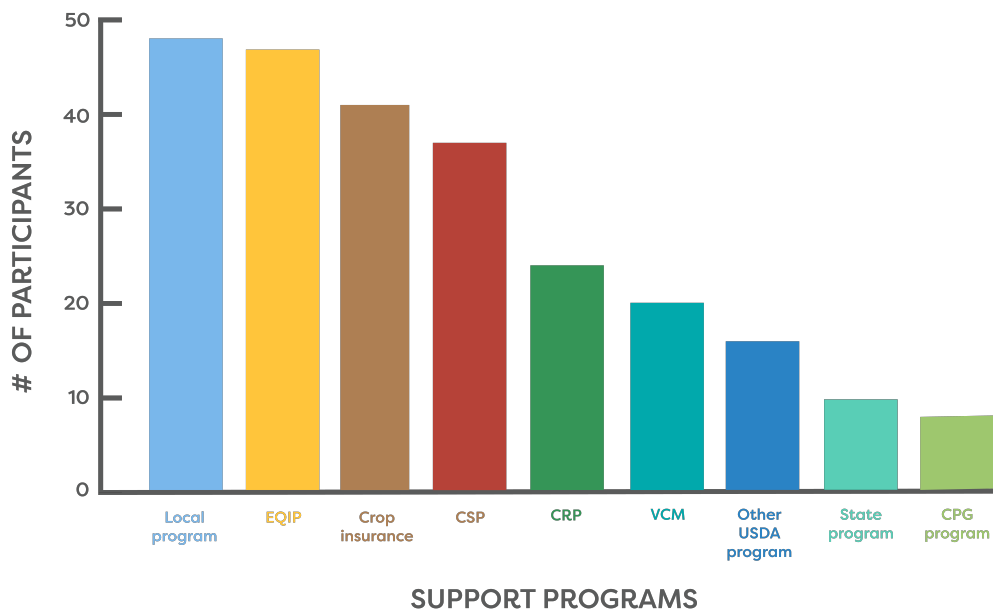


Figure 9

Experience with soil health and carbon programs reported by listening session participants

Note: Producers were enrolled across a variety of USDA conservation programs. The average row-cropper had experience across 3.6 programs and the average rancher had experience across 1.2 programs.



APPENDIX 2

Expert interviews

We also interviewed scientific experts across land-based CDR pathways to help identify the biggest barriers and opportunities for scale for each pathway. They include:

- Dr. Lord Ameyaw, University of Nebraska-Lincoln
- Dr. Andrea Basche, University of Nebraska-Lincoln
- Dr. Ashley Conway-Anderson, University of Nebraska-Lincoln
- Dr. Tim Crews, The Land Institute
- Dr. Aidee Guzman, Stanford University
- Dr. Iris Holzer, University of California Santa Barbara
- Dr. Johannes Lehmann, Cornell University
- Dr. Joseph Orefice, Yale University
- Dr. Valentin Picasso Risso, University of Wisconsin-Madison
- Cathryn Pugh, Pennsylvania State University
- Dr. Karam Sheban, University of New HampshireYale University
- Dr. Paige Stanley, Colorado State University
- Dr. Eva Stricker, Quivira Coalition and University of New Mexico
- Alicia Thompson, National Young Farmers Coalition
- Eric Toensmeier, Perennial Solutions

APPENDIX 3

Alternative risk management and financing mechanisms

PROGRAMS TO ADDRESS FINANCIAL RISKS OF CHANGING MANAGEMENT

MODEL PROJECTS	ELIGIBLE PRACTICES	US/WORLD REGION	OVERVIEW
AGREE CONSERVATION AND CROP INSURANCE RESEARCH PILOT	Cover Crops, No-Till	Midwest	Identify how cover crops and tillage affected resilience of corn and soybean yields in an extremely wet year. Foundation for COVER Act.
LAND CORE RISK MODEL	Crop rotations	Midwest	Quantify economic risk-mitigation value of specific soil health practices in response to climate events to inform lenders and insurers to develop discounts for soil health practices
GROWERS EDGE AND THE NATURE CONSERVANCY WARRANTY-BACKED CROP PLANS	Cover Crops	Midwest and Mid-Atlantic	An agronomic-backed warranty product designed to mitigate risk for farm operations and agriculture retailers to test regenerative practices
RISK MANAGEMENT PROGRAMS (E.G., CROP/DROUGHT INSURANCE)	Various	Nationwide (25 states)	Eligible farms received discounted loan interest rates from 0.25%-0.5% to acquire or refinance land that will have regenerative practices implemented. This resulted in a savings of \$5-6K per year
DELTA INSTITUTE, SOIL HEALTH AND FARMLAND VALUATION	Cover crops, no-till	Illinois	The project is a pilot that would incorporate soil health metrics into land appraisal to provide more accurate valuation of land, potentially increasing land value for land owners
MAD AGRICULTURE – MAD CAPITAL	Various	Across US	Provides loans to farmers specifically interested in transitioning into regenerative or organic practices where banks are risk-averse

Alternative risk management and financing mechanisms

PROGRAMS TO LINK SUSTAINABLE AGRICULTURE PRACTICES TO PREMIUM MARKETS

MODEL PROJECTS	ELIGIBLE PRACTICES	US/WORLD REGION	OVERVIEW
SAVING TOMORROW'S AGRICULTURAL RESOURCES	State determined	Across US (11 States)	Traditionally the STAR program is a technical assistance program to help land stewards improve their on-farm conservation efforts. Some states have been funded through the Partnerships for Climate Smart Commodities Program to link the STAR ratings with premiums for commodities.
PENNVEST PA MULTIFUNCTIONAL RIPARIAN BUFFERS	Agroforestry	Northeast	Provide funding to implement food-producing forest riparian buffers. In the long run, these can provide land managers with conservation benefits and additional income
GRAZEWELL, COUNTRY NATURAL BEEF	Sustainable Grazing	Pacific Northwest	Co-op model for ranchers using sustainable practices. GrazeWell links land management to monitoring for improvement in soil health and ecosystem services and provides the marketing, consolidation functions of a co-op system.
SUSTAINABLE COMMODITY CERTIFICATION PROGRAMS	Various	Various	A variety of certification programs for regenerative or sustainable commodities have been developed to support premium payments for commodities. It is important to note that, unlike the organic standard, there is no current nationally recognized standard of "regenerative" or "sustainable" agriculture. These certification programs all have their own standards producers must meet to enroll and some may be more focused on carbon sequestration compared to others. Examples are included here.
TREERANGE	Agroforestry poultry systems	Midwest	Consolidation model for land stewards looking to integrate silvopasture and poultry systems. Treerange provides Technical Assistance to establish trees and poultry infrastructure, initial feed for poultry and consolidates processing of land stewards who opt into this program. Feed cost is taken out of the end of marketing profits for each land stewards.

Alternative risk management and financing mechanisms

PRIVATE AND PUBLIC PROCUREMENT OF SUSTAINABLY PRODUCED COMMODITIES

MODEL PROJECTS	ELIGIBLE PRACTICES	US/WORLD REGION	OVERVIEW
CPG COMPANY REGENERATIVE AGRICULTURE PROGRAMS	Variety	Nationwide	Private CPG companies are investing in their supply chain to meet net-zero goals. As a part of this work, they are prioritizing outcomes-based approaches that support procurement of regeneratively grown agricultural commodities that protect soil health, biodiversity, and climate while supporting farm businesses. For example, Nestlé provides premiums to land stewards who implement regenerative agriculture practices and General Mills works with land stewards to provide technical assistance on implementing these practices. Both companies also estimate carbon sequestration through different monitoring methods.
STATE LEVEL PROCUREMENT PROGRAMS	Various	Various	Some states have set their own goals to support sustainable agriculture within the state, directing state agencies to procure sustainable commodities when purchasing food. For example, New York issued an executive order to support procurement of sustainable agricultural products that reduce greenhouse gases and sequester carbon. Vermont state policy has supported the procurement of sustainable agricultural products to schools.
NPS HEALTHY FOOD STANDARDS AND SUSTAINABLE FOOD GUIDELINES	Organic	Nationwide	NPS' sustainable food guidelines begin to touch on procurement of sustainable foods for concessions. At this time, these standards are not linked to specific carbon removal or conservation practices but offer an example of how federal programs can support procurement of sustainably produced food.

Alternative risk management and financing mechanisms

INTERNATIONAL POLICY INCENTIVES FOR SUSTAINABLE LAND MANAGEMENT

MODEL PROJECTS	ELIGIBLE PRACTICES	US/WORLD REGION	OVERVIEW
UK SUSTAINABLE FARMING INCENTIVE	Variety	UK	The UK government is phasing out subsidies for commodities/land tenure and directing this funding to payments to support environmental stewardship of agricultural lands
EU COMMON AGRICULTURAL POLICY	Variety	EU	Provides direct payments to farmers to implement climate interventions and to support viable farm income

Alternative risk management and financing mechanisms

NON-FEDERAL GRANTS/UPFRONT PAYMENTS FOR INNOVATIVE SOIL CARBON MANAGEMENT

MODEL PROJECTS	ELIGIBLE PRACTICES	US/WORLD REGION	OVERVIEW
MARYLAND HEALTHY SOILS COMPETITIVE FUND	Variety	MD	Provides financial assistance to land stewards who aim to manage conservation practices in new and innovative ways that improve soil health, yield, and capture carbon
ZERO FOOTPRINT	Variety	CA, CO, OR, WA	Provides grants (up to \$25K per project) for land stewards to implement regenerative practices that sequester carbon
COLORADO CLIMATE SMART MARKET EXPANSION PROJECTS	Variety	CO	Provides competitive funding (up to \$30K per project) to pilot projects that expand demand for and premiums on products grown with soil health practices
WWF SUSTAINABLE RANCHING PROGRAM	Conservation ranching	Northern Great Plains	Provides comprehensive support system for ranchers through financial assistance, technical assistance to develop sustainable grazing management plans and measurement of soil carbon

APPENDIX 4

Sources for carbon sequestration and GHG impact estimates

Table 1 summarizes carbon removal and net GHG impacts across established practices in the agricultural sector, which we have synthesized from the best available literature. We estimate both carbon removed and broader GHG impacts to ensure any claimed climate benefits are net-negative in emissions. The figures are annual averages per hectare, drawn from a literature review prepared by Mark Schonbeck. This section describes our sources and assumptions.

SOURCES

Two references anchor the table. The first is the COMET-Farm model, USDA's carbon accounting tool, whose estimates of annual soil carbon gain and woody biomass gain cover the full set of NRCS conservation practices.⁵⁸ These were the starting point for most practices. The second is a global synthesis of soil organic carbon research that pools roughly 25,000 individual studies into hundreds to thousands of paired comparisons for each practice: soil carbon measured with and without the practice.⁵⁹ We used it to compare the COMET-Farm figures with the broader literature, drawing on further meta-analyses and field studies for individual practices. Where sources diverged, we took the more conservative estimate. Below are cross-cutting sources as well as sources broken out by practice and pathway.

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ASSUMPTIONS

Scope. Each row in the table provides estimates associated with a single practice applied across an entire field or pasture. The exception is conservation buffers, whose gains apply to the planted strip rather than the whole field.

Baseline soil carbon. We used a diagram from Weil & Brady⁶⁰ to get rough estimates of typical SOC stocks (surface to 100 cm), which, in comes to about 100 metric tons per hectare for mesic (moderate to high rainfall) climates in the eastern half of the US and Pacific coastal areas, and 40 metric ton per hectare for semiarid climates. We then converted the percentages in Beillouin et al. (2023) to estimates of total SOC accruals, assuming that agroforestry practices build SOC throughout the top meter of soil, and annual cropland practices primarily enrich SOC in the top 12 inches (though there is some accrual at greater depths).

Sources for carbon sequestration and GHG impact estimates

Soil depth. Most field studies sample only the upper few inches of soil, while about half of all soil carbon sits deeper. The individual studies measured SOC stocks from surface to varying depths of 10-20-30 cm (4, 8, and 12 inches), while about half of the total SOC stock occurs below 30 cm, mostly at 30-100 cm (12-39 inches). We assumed agroforestry practices build carbon throughout the top meter, since trees root deeply, and that annual cropland practices build carbon mainly in the plow layer, with some accrual below.

Each figure is an annual average for one practice on suitable land. The ranges in the literature are wide-ranging, and real results vary widely with soil type, climate, rainfall, and practice implementation. These figures likely understate than overstate what is achievable. These estimates do not substitute for measurement for a particular site, one of the reasons this report calls for sustained investment in measurement, monitoring, reporting and verification.

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