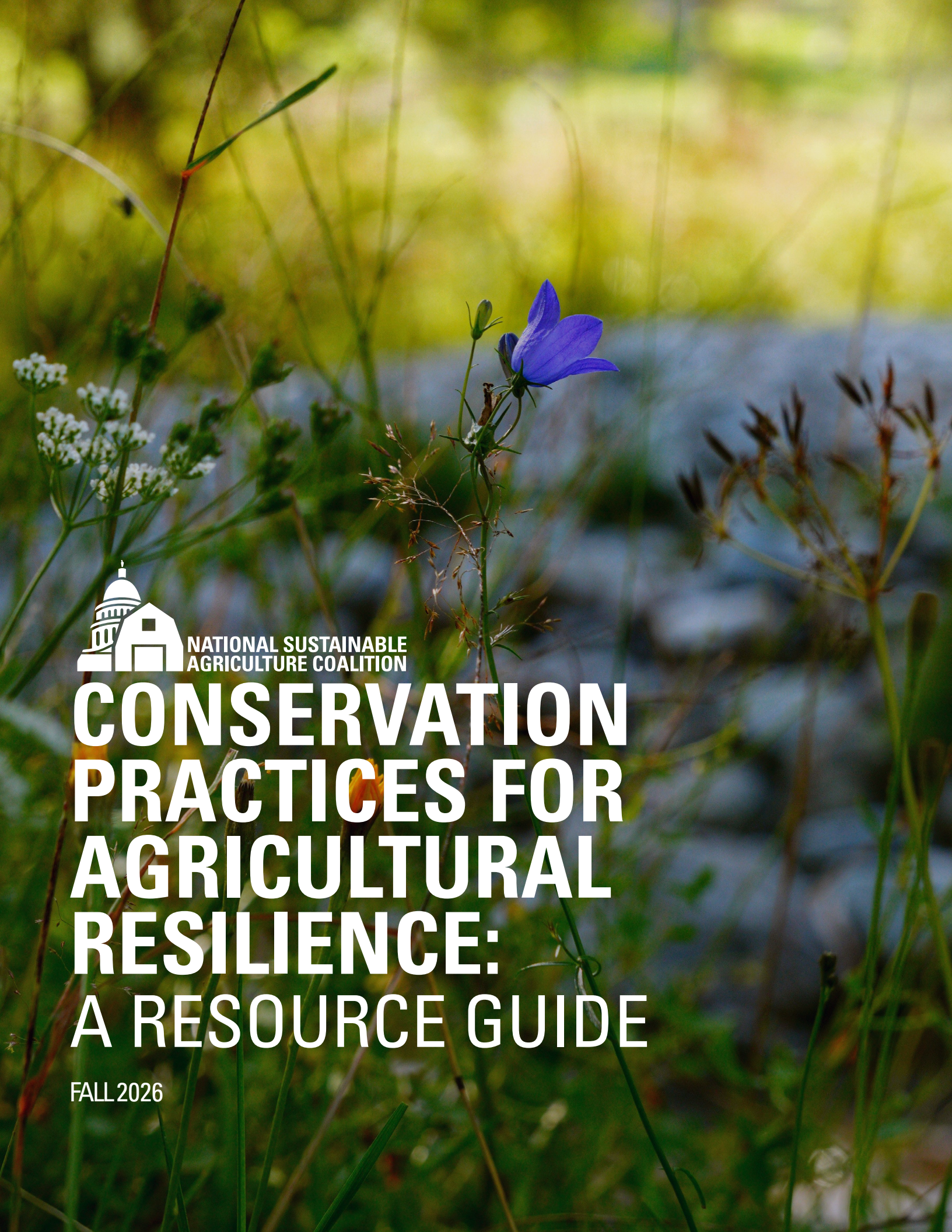


NATIONAL SUSTAINABLE AGRICULTURE COALITION

CONSERVATION PRACTICES FOR AGRICULTURAL RESILIENCE: A RESOURCE GUIDE

FALL 2026



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INTRODUCTION

Producers and land managers are experiencing firsthand impacts of extreme weather events and other environmental stresses, in part caused by the build-up of greenhouse gases (GHGs) in the atmosphere. This resource guide presents a subset of the US Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) Conservation Practice Standards (CPS) that can help farmers build the resilience of their production systems and surrounding communities to the impacts of climate change. These practices build soil health and fertility, enhance infiltration and water holding capacities, protect water quality, reduce input costs, mitigate the impact of drought, flood, and other extreme weather events on crops and livestock, support biodiversity, and provide other long-term ecological and economic benefits.

NRCS works with farmers to address natural resource concerns: specific issues where natural resources are degraded to the extent that sustainability or intended use is impaired. NRCS identifies resource concerns under the broad categories of Soil, Water, Air, Plants, Animals, and Energy, each of which includes specific concerns such as soil erosion, soil quality degradation, impaired water quality, insufficient water quantity, inadequate wildlife habitat, and greenhouse gas emissions. The complete **list of NRCS resource concerns** embraces most of the leading environmental challenges associated with farming, ranching, and other land uses. Practices that address multiple resource concerns, such as those listed below, also build farm resilience to severe climate impacts.

Working with NRCS, producers engage in a collaborative **nine-step process** to develop conservation plans. This process, which moves from identifying an operation's resource concerns to helping producers implement and evaluate practices, is part of a holistic planning approach that helps create more resilient operations. Practices can be combined and customized to fit an operation's specific goals, resources, and regional conditions. It is our hope that this guide will be used to enhance the broader, holistic planning process producers engage in with NRCS, and in conjunction with other resources that allow producers to understand the climate, ecological, and economic benefits of practices on their operation.

This guide begins with a non-exhaustive listing of NRCS conservation practice standards with climate benefits, detailing the resource concerns addressed with each practice and how it can be combined with other practices for greater efficacy and synergy. Those practices are followed by examples of how they can be combined to achieve specific goals. For a robust list of references, including for greenhouse gas estimations, see the attached literature review.

NRCS publishes national standards that contain further information on implementing a conservation practice, but these are not used to design or install practices; instead, states adapt and modify these standards to meet state and local criteria. While this guide links to national practice standards, state standards can be found in the NRCS **Field Office Technical Guide Application.**

CONSERVATION PRACTICE STANDARDS

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
311 ALLEY CROPPING **An agroforestry practice where agronomic, horticultural, or forage crops are grown in the alleyways between widely spaced rows of woody plants.**  Photo: USDA NRCS	● **Soil** – Greatly reduces sheet and rill, wind, and ephemeral gully erosion. Builds soil health and soil organic matter (SOM); provides habitat for a greater density and diversity of soil organisms. ● **Water** – Reduces nutrient transport to surface and ground water through improved nutrient cycling efficiency and reduced fertilizer needs. Traps drifting snow, mitigates seasonal high water table, and increases use efficiency of naturally available water and irrigation. ● **Air** – Tree rows intercept particulate matter (dust) and pesticide spray drift (ozone precursors). Emissions of GHGs – Sequesters 800-1,200 lb C/ac-year in soil and woody biomass, may reduce N_2O by 0.5-1.0 lb N_2O-N/ac-yr by reducing N input needs and intercepting excess soluble N. ● **Plants** – Improves (diversifies) plant community structure and composition, reduces plant pest pressure, and enhances plant productivity and health by mitigating microclimate (wind, heat, cold). ● **Animals** – Provides habitat for wildlife and beneficial organisms. Provides shelter from wind or temperature extremes for livestock grazing on forage alley crops.	327 Conservation Cover 328 Conservation Crop Rotation 340 Cover Crop 528 Grazing Management 590 Nutrient Management 512 Pasture and Hay Planting 595 Pest Management Conservation System 345 Residue and Tillage Management, Reduced Till 612 Tree/Shrub Establishment 384 Woody Residue Treatment **NOTES** Alley cropping is, in effect, a highly integrated bundle of practices that is incredibly versatile and provides a viable pathway towards building highly resilient agro-ecosystems.

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
317 COMPOSTING FACILITY **A structure or device to contain and facilitate the controlled aerobic decomposition of manure or other organic material by microorganisms into a biologically stable organic material that is suitable for use as a soil amendment.**  Photo: USDA NRCS	**Benefits of Compost:** ● **Soil** – Compost benefits include building SOM, providing soil organism habitat, and improved soil aggregation. ● **Water** – Improves naturally available moisture use through improved infiltration and soil moisture retention. Reduces nutrient transport to surface and groundwater by stabilizing manure nutrients and reducing fertilizer input needs. ● **Plants** – Improves plant productivity and health, reduces plant pest pressure (disease suppression). **Benefits of Facility:** ● **Water** – Reduces transport of nutrients, pathogens, chemicals, and salts to surface and groundwater. Promotes on-farm nutrient cycling and reduces nutrient losses. ● **Air** – Emissions of GHGs – Less GHG emissions than alternative fates of materials (lagoon or static dry stack for manure, landfill or burn pile for yard trimmings, food waste, fine fuel removal from forests, etc.)	590 Nutrient Management 367 Roofs and Covers 558 Roof Runoff Structure 336 Soil Carbon Amendment 313 Waste Storage Facility **NOTES** This practice and other waste management practices such as CPS 313 Waste Storage Facility, CPS 632 Waste Separation Facility, and CPS 634 Waste Transfer may additionally be used to help dairy and livestock operations take on alternative, or non-digester, manure management practices, such as compost bedded pack barns, solid separation, and conversion from flush to dry scrape manure collection. Such options are accessible, cost-effective, and reduce risk of water pollution, enhance air quality, and improve a farm's ability to recycle manure as natural compost for healthy soils.

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
327 CONSERVATION COVER **Establishing and maintaining permanent vegetative cover.**	● **Soil** – Reduces sheet, rill, and wind erosion. Permanent vegetation increases roots and organic matter and improves all aspects of soil health. ● **Water** – Reduces need for pesticides, reduces sediment transport to surface waters (decreases runoff and erosion), reduces nutrient transport to surface and groundwater (permanent cover can take up excess nutrients). ● **Air** – Emissions of GHGs – Substantial carbon sequestration in soil and biomass, estimated at 780 lb/ac-yr in COMET Farm. ● **Animals** – Increased quality and quantity of vegetation provides more food and habitat for wildlife and beneficials.	314 Brush Management 342 Critical Area Planting 612 Tree/Shrub Establishment 645 Upland Wildlife Habitat Management



Photo: Doug Crabtree, Vilicus Farms, Havre, MT

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
328 CONSERVATION CROP ROTATION **Growing a planned sequence of various crops on the same piece of land for a variety of conservation purposes.**	● **Soil** – Reduces sheet, rill, and wind erosion through sufficient canopy and residue cover. Increases soil organic matter and improves soil health, organism habitat, and aggregation. Reduces concentration of salts. ● **Water** – Reduces transport of nutrients to surface and groundwater; improves use efficiency of naturally available moisture and irrigation water. ● **Air** – Emissions of GHGs – Soil organic carbon (SOC) sequestration may vary from negligible to ~300 lb/ac-yr depending on how it is implemented. ● **Plants** – Improves plant productivity and health through crop selection, reduces plant pest pressure due to crop diversity.	513 Annual Forages for Grazing Systems 330 Contour Farming 340 Cover Crop 590 Nutrient Management 595 Pest Management Conservation System 329 Residue and Tillage Management, No Till 345 Residue and Tillage Management, Reduced Till 585 Stripcropping 600 Terrace



Photo: NSAC

NOTES

Taking on this conservation practice likely reduces input costs and improves yield and farm income stability over monoculture systems.

General criteria for this practice require two or more crops in rotation. All benefits listed are maximized by a crop rotation that addresses all four NRCS principles of soil health: maximize year-round cover and living root (minimize fallow), increase diversity, and minimize chemical, physical, and biological disturbance to the soil. A diverse rotation in conjunction with best nutrient management practices can also lower N_2O emissions by 1-3 lb N/ac-yr.

The Conservation Stewardship Program Supplemental Payment for Resource-Conserving Crop Rotations (RCCR) provides the upper end potential for SOC sequestration, which may be even higher depending on how long the perennial resource conserving crop remains in place without tillage.

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
332 CONTOUR BUFFER STRIPS **Strips of perennial grass alternated with wider cultivated strips that are farmed on the contour. Vegetation of strips consists of adapted species of grasses or mixture of grasses and legumes.**  Photo: USDA NRCS	● **Soil** – Maintaining vegetation on contour reduces sheet and rill erosion. ● **Water** – Reduces transport of sediment, nutrients, and pesticides to surface waters. Promotes efficient use of naturally available moisture and irrigation water by improving moisture infiltration into the soil. ● **Air** – Emissions of GHGs – Area under the buffer may build ~780 lb SOC + biomass C/ac-yr (from COMET Farm 2016). ● **Plants** – May improve biodiversity and biological pest control depending on species planted in the buffer.	328 Conservation Crop Rotation 340 Cover Crop 412 Grassed Waterway 590 Nutrient Management 595 Pest Management Conservation System 329 Residue and Tillage Management, No Till 345 Residue and Tillage Management, Reduced Till

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
340 COVER CROP **Grasses, legumes, and other forbs planted for seasonal vegetative cover.**  Photo: USDA NRCS	● **Soil** – Reduces erosion of all kinds, builds soil organic matter and soil organism habitat, improves aggregation, drainage, aeration, and water infiltration, reduces compaction. ● **Water** – Improves efficiency of naturally available moisture use. Reduces transport of nutrients to surface and ground water (takes up excess soil nutrients and legumes reduce need for applied N). ● **Air** – Emissions of GHGs – Basic cover cropping practices add ~210 lb SOC/ac-yr, reaching a plateau at about 12% increase in SOC stocks. ● **Plants** – Improves plant productivity and health, especially N fixing legumes, and reduces plant pest pressure as it suppresses weeds, provides habitats for beneficials, and can disrupt lifecycles of pathogens and pests through diversified rotation. ● **Animals** – Provides habitat for beneficial insects and forage for livestock.	328 Conservation Crop Rotation 331 Contour Orchard or other perennial crops 528 Grazing Management 590 Nutrient Management 595 Pest Management Conservation System 329 Residue and Tillage Management, No Till 345 Residue and Tillage Management, Reduced Till 336 Soil Carbon Amendment 585 Stripcropping

NOTES

High biomass intensive cover cropping/continuous living cover can sequester 300-350 lb SOC/ac-yr and ultimately enhance SOC stocks by 30%. Functionally diverse cover crops (e.g., grass + legume + crucifer) build more SOC than monoculture grass or legume of similar biomass and duration.

Tilling in a cover crop may increase N_2O emissions by 1-3 lb/ac-yr (which could negate the 129-387 lb/ac C sequestration), especially if it is a legume or other low C:N cover crop. Tilling in a succulent, high-N legume adds readily mineralizable N and readily consumed (by microbes) organic C to biologically active soil and can create ideal conditions for N_2O formation. The tradeoff may depend on how accurately a legume is credited in adjusting N fertilizer rates, on how it is tilled, and further environmental factors.

Tilling any cover crop at the same time as manure, poultry litter, or synthetic N is applied can cause N_2O releases of 9 lb/ac or more, which may negate C sequestration.

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
342 CRITICAL AREA PLANTING **Establishes permanent vegetation on sites that have, or are expected to have, high erosion rates, and on sites that have conditions that prevent the establishment of vegetation with normal practices.**  Photo: USDA NRCS	● **Soil** – Prevents or reduces erosion, including shore/streambank erosion. Builds soil organic matter and restores soil health in the treated area. ● **Water** – Reduces transport of sediment to surface waters. ● **Air** – Emissions of GHGs – Sequesters soil and biomass carbon at rates similar to those cited in COMET Farm for other herbaceous and woody perennial plantings (780 and 1020-1500 lb/ac-yr, respectively).	362 Diversion 315 Herbaceous Weed Treatment 484 Mulching 590 Nutrient Management 500 Obstruction Removal 606 Subsurface Drain 612 Tree/Shrub Establishment 620 Underground Outlet

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
386 FIELD BORDER **Strips of permanent vegetation (grasses, legumes, forbs, or shrubs) established on one or more sides of a field.**  Photo: USDA NRCS	● **Soil** – Reduces sheet, rill, and wind erosion, builds soil organic matter and soil health within the field border planting. ● **Water** – Reduces transport of nutrients to surface and groundwater. Reduces transport of sediment to surface water. ● **Air** – Reduces emissions of particulate matter. Emissions of GHGs – Can sequester ~780 lb C/ac-yr in soil and perennial biomass (roots, woody shrubs if these are included) within the field border area. ● **Plants** – Improves plant productivity and health (habitat for pollinators), reduces plant pest pressure (habitat for natural enemies of pests). ● **Animals** – Provides habitat and vegetation for wildlife and beneficial organisms. **NOTES** Field borders may be harvested for nuts, fruits, or herbs for a diversified income stream if conservation benefits are maintained. A field border can also provide a buffer to protect USDA certified organic production areas from pesticide spray and GMO pollen drift. Planting a diverse field border of several functional groups (warm/cool season, grass, legume, other forbs, shrubs) may sequester more carbon in soil and root biomass than a monoculture such as switchgrass or miscanthus alone.	327 Conservation Cover 328 Conservation Crop Rotation 647 Early Successional Habitat Development/Management 512 Pasture and Hay Planting 329 Residue and Tillage Management, No Till 345 Residue and Tillage Management, Reduced Till 612 Tree/Shrub Establishment 645 Upland Wildlife Habitat Management 644 Wetland Wildlife Habitat Management

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
393 FILTER STRIP **An area of vegetation established for removing sediment, organic material, and other pollutants from runoff and wastewater.**  Photo: NSAC	● **Water** – Protects surface water quality. Reduces transport of sediment, and any adsorbed nutrients and other contaminants to surface waters. Can protect organic production areas from runoff containing substances prohibited under the National Organic Program standards. ● **Air** – Emissions of GHGs – Can sequester ~780 lb C/ac-yr in soil and grass roots within the filter strip area.	340 Cover Crop 328 Conservation Crop Rotation 528 Grazing Management 590 Nutrient Management 595 Pest Management Conservation System 329 Residue and Tillage Management, No Till 345 Residue and Tillage Management, Reduced Till

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
379 FOREST FARMING **Maintaining or establishing stands of trees or shrubs in coordination with the management and/or cultivation of understory plants or nontimber forest products.**  Photo: NSAC	● **Soil** – Reduces soil erosion of all kinds. Builds soil health, soil organic matter, and soil microbial functional diversity. ● **Water** – Reduces nutrient transport to surface and groundwater by improving nutrient cycling efficiency and reducing fertilizer input needs. Increases irrigation efficiency and efficient use of naturally available water. ● **Air** –Trees intercept dust, spray, and drift. Provides mitigation of wind, heat, and cold. Emissions of GHGs – Conversion of treeless cropland to forest farming sequesters at least 800-1,200 lb C/ac-year in soil and woody biomass, and it may reduce N_2O by 0.5-1.0 lb N_2O-N/ac-yr by reducing N input needs and intercepting excess soluble N. ● **Plants** – Improves plant community structure and composition, restores native plants, reduces plant pest pressure. ● **Animals** – Provides habitat for wildlife and beneficial organisms.	472 Access Control 666 Forest Stand Improvement 612 Tree/Shrub Establishment 660 Tree/Shrub Pruning 490 Tree/Shrub Site Preparation **NOTES** This practice should be prioritized in the scenario where it is implemented on treeless cropland or grazing land, perhaps as a successional process starting with 311 Alley Cropping or 381 Silvopasture. If existing woodland is converted to forest farming, there is little further change in C sequestration. However, forest farming can be beneficial if implemented on degraded woodland. For example, if trees are in poor health, overcrowded, or being invaded by invasive plant species, practices such as 314 Brush Management or 315 Herbaceous Weed Treatment may be used to address these issues, followed by plantings.

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
383 FUEL BREAK **A strip or appropriately sized block of land on which the vegetation, debris, and litter have been reduced and/ or modified to control or diminish the spread of fire.**	● **Plants** – Protects plant productivity and health by reducing risk of severe wildfires. Facilitates management of forage quality and plant productivity and health with prescribed fire. ● **Air** – Emissions of GHGs –There may be an initial loss of biomass and soil carbon in creating the fuel break, followed by recovery of SOC and root biomass C as the fire-resistant grass-forbs planting becomes established. Mitigation of wildfires prevents huge CO_2 emissions and significant emissions of other GHGs. ● **Animals** – Protects wildlife, beneficial organisms, and domestic livestock by reducing risk of severe wildfires. Facilitates maintenance of wildlife habitat and forage quality and quantity for livestock through prescribed fire.	511 Forage Harvest Management 528 Grazing Management 512 Pasture and Hay Planting 550 Range Planting **NOTES** Fuel breaks are well planted with perennial herbaceous vegetation (CPS 512, CPS 550), especially fire-resistant species managed by mowing (CPS 511) or grazing (CPS 528) so that the fuel break slows the spread of fires.



Photo: USDA NRCS

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
412 GRASSED WATERWAY **Shaped or graded channel that is established with suitable vegetation to convey surface water at a nonerosive velocity using a broad and shallow cross section to a stable outlet.**	● **Soil** – Shaping or grading, followed by establishment of perennial grass, prevents gully erosion. ● **Water** – Reduces sediment transport to surface water. ● **Air** – Emissions of GHGs – Can sequester ~780 lb C/ac-yr in soil and grass roots within the waterway planting.	342 Critical Area Planting 362 Diversion 410 Grade Stabilization Structure 600 Terrace Other erosion control practices*



Photo: USDA NRCS

*For a broader list of specific practices, refer to NRCS resources and staff or your conservation partner.

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
528 GRAZING MANAGEMENT **Managing vegetation with grazing and browsing animals to achieve specific ecological, economic, and management objectives.**  Photo: USDA NRCS	● **Soil** – Reduces sheet, rill, wind, gully, and streambank erosion and improves all aspects of soil health including organic matter, habitat for soil organisms, aggregate stability, and reduced compaction. ● **Water** – Reduces transport of sediment, nutrients, pathogens, and chemicals to surface and groundwater. Improves efficient use of naturally available moisture and mitigates depletion of surface and groundwater by enhancing watershed hydrology and function. ● **Air** - Emissions of GHGs – Findings on net C sequestration for rotational grazing vary widely from no net GHG mitigation to 1 to 2 tons SOC/ac-yr for the first several years after conversion from either cropland or unmanaged grazing to sound, regionally appropriate rotational grazing or other advanced grazing management. Timely rotation among paddocks and strategic placement and movement of shade structures and watering stations to improve manure distribution can minimize N_2O "hotspots" related to manure accumulations. Improved forage qualities may additionally cut ruminant enteric methane emissions by 30-50%. ● **Plants** – Improves plant productivity and health, community structure and composition, and reduces plant pest pressure by suppressing invasive and undesirable plant species. ● **Animals** – Improves quality, quantity, and year round availability of livestock forage. Improves terrestrial and aquatic habitats for wildlife, fish, and other organisms. **NOTES** Advanced grazing management and management intensive rotational grazing provide best results for carbon sequestration. This practice additionally reduces wildfire risk and facilitates prescribed burning by managing biomass accumulation/ fuel loads.	513 Annual Forages for Grazing Systems 382 Fence 511 Forage Harvest Management 561 Heavy Use Area Protection 315 Herbaceous Weed Treatment 516 Livestock Pipeline 576 Livestock Shelter Structure 590 Nutrient Management 512 Pasture and Hay Planting 595 Pest Management Conservation System 550 Range Planting 381 Silvopasture 578 Stream Crossing 614 Watering Facility 420 Wildlife Habitat Planting 380 Windbreak/Shelterbelt Establishment and Renovation

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
422 HEDGEROW PLANTING **Establishment of dense vegetation in a linear design to achieve a conservation purpose.**  Photo: NSAC	● **Soil** – Improves soil health within and near the hedgerow. Reduces soil erosion. ● **Air** – Intercepts emissions of particulate matter (dust, pollen), ozone precursors (pesticide spray drift), and odors. A tall, dense hedgerow can mitigate local microclimate and protect organic production areas from exposure to pesticide spray and GMO pollen drift. Emissions of GHGs – Can sequester 1,000 lb or more C/ac-yr in soil and woody biomass within the hedgerow planting. May help mitigate N_2O by taking up soluble N. ● **Plants** – Improves plant productivity and health (habitat for pollinators) and reduces plant pest pressure (habitat for natural enemies of pests). Enhances plant structure and composition through biodiversity. ● **Animals** – Provides habitat for wildlife and invertebrates.	484 Mulching 490 Tree/Shrub Site Preparation 612 Tree/Shrub Establishment 660 Tree/Shrub Pruning 645 Upland Wildlife Habitat Management **NOTES** This practice may diversify enterprise and income streams if hedgerows provide marketable harvests.

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
449 IRRIGATION WATER MANAGEMENT **The process of determining and controlling the volume, frequency, and application rate of irrigation water.**	● **Soil** – Reduces water erosion by irrigation, and manages concentration of salts in the root zone. ● **Water** – Improves efficiency of irrigation water use. Reduces transport of sediment to surface waters, reduces transport of nutrients and chemicals to surface and groundwater. ● **Plants** – Improves plant productivity and health. ● **Energy** – Reduces energy use for irrigation.	328 Conservation Crop Rotation 340 Cover Crops 430 Irrigation Pipeline 441 Irrigation System, Microirrigation 590 Nutrient Management 595 Pest Management Conservation System



Photo: USDA NRCS

NOTES

Microirrigation can enable more efficient water use and greater resilience to weather variability, with co-benefits of energy savings and lower input costs.

With limited water supply, producers may also consider transitioning to dryland farming using support from other conservation practices or USDA programs.

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
484 MULCHING **Applying plant residues or other suitable materials to the land surface.**	● **Soil** – Reduces sheet, rill, wind, gully, and streambank erosion. Organic mulch builds soil organic matter, provides food and habitat for soil organisms, and improves surface porosity. ● **Water** – Improves the efficiency of naturally available moisture use and irrigation water use (reduces evaporative losses, improves water infiltration and storage). ● **Air** – Reduces particulate matter emissions (dust). Emissions of GHGs – May enhance SOC sequestration to some degree, especially if plant growth and biomass are benefitted. ● **Plants** – Improves plant productivity and health, reduces plant pest pressure (suppresses weeds, especially film or fabric mulches and provides habitat for natural enemies of pests, especially organic mulches).	328 Conservation Crop Rotation 342 Critical Area Planting 362 Diversion 441 Microirrigation 590 Nutrient Management 612 Tree/Shrub Establishment 380 Windbreak/Shelterbelt Establishment and Renovation Other vegetation establishment practices*



Photo: NSAC

NOTES

Mulching is often used in annual crops, especially vegetables. Organic mulches add varying amounts of nutrients, especially N and K, which should be considered in a nutrient budget. Organic mulches can harbor certain pests such as slugs and squash bugs.

Synthetic film mulches block weeds more effectively than organic mulches, but do not feed soil life and may promote concentrated flow and severe erosion in alleys between mulched beds on sloping fields and ponding in level fields.

Plastic mulches that are fossil fuel based add to the GHG footprint of the system.

Microirrigation under plastic can ensure adequate water availability for crops and can be helpful under organic mulches in drier climate or during drought.

*For a broader list of specific practices, refer to NRCS resources and staff or your conservation partner.

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS

590 NUTRIENT MANAGEMENT

Manage rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impact.



Photo: USDA NRCS

- **Soil** – Improves soil health and soil organic matter.
- **Water** – Reduces transport of nutrients to surface and ground waters by balancing nutrient inputs with plant needs. Reduces transport of pathogens from manure and other amendments to surface and groundwaters.
- **Air** – Reduces emissions of particulate matter, ozone precursors, odors (ammonia), and nitrous oxide.

Emissions of GHGs – Estimates have net GHG benefits (N_2O mitigation in CO_2-C equivalents) at just 90 lb/ac-yr for "nutrient management - improved N fertilizer" and 1,080 lb/ac-yr if all N can be derived from soil organic matter mineralization. Reductions in application rates of synthetic N also reduce the embodied GHG emissions in fertilizer manufacture (~1.2 lb CO_2-C per 1 lb fertilizer N).

- **Plants** – Improves plant health and productivity, may reduce plant pest pressure (weeds and other pests stimulated by overapplication of nutrients).

NOTES

Nutrient management can reduce production costs, from fertilizer purchase to clearing regulatory hurdles related to water pollution.

The benefits of nutrient management for N_2O mitigation, fertilizer cost savings, protecting water quality, and improving soil health are best realized when fully crediting the N released from soil organic matter, cover crop residues, and organic soil amendments as well as emphasis on moderate C:N, slow-release organic N sources.

Avoiding surplus N and P can also improve soil microbial functional diversity and enhance SOC sequestration.

Systems that use organic nutrient sources need to pay close attention to P to avoid buildup of excesses, which can degrade water quality and inhibit vital mycorrhizal fungi that support SOC sequestration and N_2O mitigation.

Predicting and moderating N_2O emissions can be challenging, especially in soil health systems that emphasize organic amendments and nutrient sources. Ongoing research is making advances in N_2O management in farming systems that utilize legumes, manure, and other organic N sources.

Precision agriculture with conventional fertilizers and inputs has limited capacity to mitigate GHG or build SOC. Research advances in organic nutrient management may expand benefits of precision approaches.

- 317 Composting Facility
- 328 Conservation Crop Rotation
- 332 Contour Buffer Strips
- 330 Contour Farming
- 340 Cover Crop
- 393 Filter Strip
- 528 Grazing Management
- 484 Mulching
- 329 Residue and Tillage Management, No Till
- 345 Residue and Tillage Management, Reduced Till
- 391 Riparian Forest Buffer
- 390 Riparian Herbaceous Cover
- 336 Soil Carbon Amendment
- 585 Stripcropping
- 633 Waste Recycling
- 632 Waste Separation Facility
- 313 Waste Storage Facility

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS

512 PASTURE AND HAY PLANTING

Establishing adapted and compatible species, varieties, or cultivars of perennial herbaceous plants suitable for pasture or hay production.



Photo: USDA NRCS

- **Soil** – Reduces sheet, rill, wind, and gully erosion, builds soil organic matter and soil health.
- **Water** – Reduces transport of sediment to surface waters and transport of nutrients to surface and groundwater if not overfertilized.
- **Air** – Emissions of GHGs – Converting cropland to pasture can sequester substantial C in soil and biomass, potentially ~780 lb/ac-yr.
- **Animals** – Improves quality, quantity, and year round availability of livestock forage. Maintains livestock nutrition and health.

- 382 Fence
- 511 Forage Harvest Management
- 528 Grazing Management
- 315 Herbaceous Weed Treatment
- 590 Nutrient Management
- 645 Upland Wildlife Habitat Management

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
595 PEST MANAGEMENT CONSERVATION SYSTEM **A system that combines an Integrated Pest Management (IPM) decision making process with natural resource conservation to address pest and environmental impacts.**	● **Soil** – Reduces erosion, organic matter depletion, and soil compaction and enhances habitat for soil life. ● **Water** – Reduces transport of pesticides to surface and groundwater. ● **Air** – Reduces emissions of particulate matter precursors (spray droplet drift) and ozone precursors (volatile organic compounds or VOCs). Emissions of GHGs – Pesticides contain ~3-11 lb embodied CO_2-C per 1 lb active ingredient in their manufacture. This does not include the embodied CO_2-C in inert ingredients used to formulate pesticides for field application, the composition of which is often undisclosed. In addition, some pesticides adversely affect soil biology and microbiomes in ways that can compromise the soil's capacity to sequester carbon, mitigate nitrous oxide formation, and to generate and deliver plant nutrients and provide disease suppression. ● **Plants** – Reduces plant pest pressure. ● **Animals** – Reduces pesticide impacts on nontarget organisms including pollinators, natural enemies of pests, fish, and wildlife. **NOTES** A pest management conservation system that prioritizes prevention, avoidance, monitoring, and biological and cultural methods of pest suppression can greatly reduce the need for pesticides, which can help protect soil life, mitigate the risk of pesticide resistance, and reduce input costs. Integrated weed management that reduces reliance on tillage and cultivation protects soil health and reduces compaction and erosion. Additionally reduces exposure of farmers, farmworkers, and nearby communities to hazardous pesticides.	311 Alley Cropping 317 Composting Facility 328 Conservation Crop Rotation 327 Conservation Cover 340 Cover Crop 386 Field Border 379 Forest Farming 528 Grazing Management 422 Hedgerow Planting 325 High Tunnel Systems 821 Low Tunnel Systems (interim) 484 Mulching 590 Nutrient Management 329 Residue and Tillage Management, No Till 345 Residue and Tillage Management, Reduced Till 381 Silvopasture 585 Stripcropping 380 Windbreak/Shelterbelt Establishment and Renovation



Photo: NSAC

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
550 RANGE PLANTING **Seeding and establishment of herbaceous and woody species for the improvement of vegetation composition and productivity of plant communities to meet management goals.**	● **Soil** – Reduces erosion by wind and water; increases organic matter. ● **Water** – Protects quality and quantity of the scarce water resources in dry regions; restores hydrological function. ● **Air** – Emissions of GHGs – SOC and biomass C accrue only slowly in semiarid or arid rangeland, but the gradual increases realized from range planting and best grazing management (60-100 lb C/ac-yr) may continue for several decades. ● **Animals** – Provides wildlife and beneficial habitat (forage, browse, cover) and improves quality, quantity, and year-round availability of forages for livestock. ● **Plants** – Improved plant productivity and health. Restores plant community structure and composition, protects ecosystem functions and biodiversity.	314 Brush Management 548 Grazing Land Mechanical Treatment 528 Grazing Management 315 Herbaceous Weed Treatment 338 Prescribed Burning **NOTES** Planting a functionally diverse mixture of native prairie species (cool season and warm season grasses, legumes, other forbs) can enhance soil organic carbon over monoculture.



Photo: USDA NRCS

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS

329 RESIDUE AND TILLAGE MANAGEMENT, NO TILL

Addresses the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round. Crops are planted and grown in narrow slots or tilled strips established in the untilled seedbed of the previous crop.



Photo: NSAC

- **Soil** – Reduces sheet, rill, and wind erosion and can improve soil health, especially near-surface aggregation, soil organic matter, and water infiltration. Benefits to soil organisms and their habitat vary depending on other practices (rotation, cover crop, agrochemical inputs, etc.)
- **Water** – Reduces sediment transport to surface waters.
- **Air** – Reduces particulate matter (dust from tillage).

Emissions of GHGs – Can sequester SOC at ~270 lb/ac-yr for the first 10-15 years, reaching a plateau at ~10% increase in SOC stocks. SOC accrued through no-till is readily lost with even a single tillage pass (often needed every few years to manage weeds or relieve compaction). Effects on N_2O are variable – can mitigate if legume cover crops are terminated no-till; can increase slightly if heavy residue keeps soil too wet.

- **Energy** – Reduces energy use in field operations.

328 Conservation Crop Rotation

340 Cover Crop

590 Nutrient Management

595 Pest Management Conservation System

336 Soil Carbon Amendment

585 Stripcropping

NOTES

No-till by itself can have limited soil health benefits, especially if done with conventional inputs and no or inadequate cover cropping. These conditions can lead to increased compaction or reduced soil aeration which, in turn, can limit soil microbial biomass and activity. Conservation tillage reduces sediment in runoff most effectively when applied in conjunction with a sound rotation and effective high biomass cover crops.

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS

345 RESIDUE AND TILLAGE MANAGEMENT, REDUCED TILL

Manages the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round while limiting the soil-disturbing activities used to grow and harvest crops in systems where the field surface is tilled prior to planting.



Photo: Justin Rich, Burnt Rock Farm, Huntington, VT

- **Soil** – Reduces soil erosion, can improve soil health, especially microbial activity. Gradually builds soil organic matter, improves aggregation.
- **Water** – Reduces sediment transport to surface waters.
- **Air** – Reduces particulate matter (dust from tillage).

Emissions of GHGs – Accrues SOC at slower rates (110-180 lb/ac-yr) than no-till (~270 lb/ac-yr) but attains similar plateau (10% increase in SOC stocks). Improves microbial activity and formation of stable SOC over either no-till or full inversion tillage. Effects on N_2O are minor unless the tillage operations incorporate legume green manure or N fertilizer + any cover crop.

- **Energy** – Reduces energy use in field operations.

328 Conservation Crop Rotation

340 Cover Crop

590 Nutrient Management

595 Pest Management Conservation System

336 Soil Carbon Amendment

585 Stripcropping

NOTES

Reduced tillage is implemented by a growing percentage of organic producers; in conjunction with organic practices (cover crops, amendments, etc.) it can maintain excellent soil health for crop production.

Reduced tillage maintains twice the microbial biomass as either full tillage or continuous no-till. Microbial activity plays a central role in transforming residues and root exudates into the most stable form of soil organic carbon.

Terminating cover crops by roller-crimper to avoid N_2O emissions from mixing legume residues into the soil can be part of an overall reduced-tillage system (rotational no-till - often practiced by organic farmers).

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
391 RIPARIAN FOREST BUFFER **An area predominantly covered by trees and/or shrubs located adjacent to and up-gradient from a watercourse or water body.**  Photo: USDA NRCS	● **Soil** – Reduces erosion (especially streambank) and greatly improves soil health in the buffer area. ● **Water** –The best practice for protecting water quality of streams. Greatly reduces transport of sediment to surface waters and transport of nutrients, pathogens, pesticides, and other chemicals to surface and groundwaters. ● **Air** – Can protect crops and pasture from particulates (dust), ozone precursors (pesticide spray drift), and pollen from across the river (important for organic production and crop seed production). Can mitigate microclimate for nearby crops and pasture. Emissions of GHGs – Can sequester ~1,500 lb C/ac-yr or more in soil + woody biomass within the buffer area, may reduce N_2O emissions by intercepting and taking up soluble N. ● **Plants** – Restores diversity, structure, and composition of riparian plant communities. ● **Animals** – Improves terrestrial habitat for wildlife and invertebrates, improves aquatic and riparian habitat for fish and other organisms. Mitigates elevated water temperatures.	472 Access Control 328 Conservation Crop Rotation 340 Cover Crop 382 Fence 516 Livestock Pipeline 576 Livestock Shelter Structure 590 Nutrient Management 390 Riparian Herbaceous Cover 580 Streambank and Shoreline Protection 578 Stream Crossing 395 Stream Habitat Improvement and Management 612 Tree/Shrub Establishment 614 Watering Facility

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
390 RIPARIAN HERBACEOUS COVER **Establishment and maintenance of grasses, grass-like plants, and forbs that are tolerant of intermittent flooding or saturated soils and that are established or managed in the transitional zone between terrestrial and aquatic habitats.**  Photo: USDA NRCS	● **Soil** – Reduces streambank erosion from water flow, stabilizing streambanks and shorelines. Builds soil organic matter and soil health in the area under riparian herbaceous cover. ● **Water** – Reduces transport of nutrients, pesticides, and sediment to surface waters. ● **Air** – Emissions of GHGs – Can sequester ~780 lb C/ac-yr in soil and perennial biomass within the area planted to herbaceous cover. Can reduce N losses to waterways and thereby reduce off-site N_2O formation. ● **Plants** – Improves plant productivity and health (pollinator habitat) and improves plant structure and composition through biodiversity. ● **Animals** – Provides terrestrial habitat and vegetation for wildlife and invertebrates, and improves aquatic habitat for fish and other organisms. May be used as livestock forage if properly maintained.	472 Access Control 328 Conservation Crop Rotation 340 Cover Crop 382 Fence 528 Grazing Management 516 Livestock Pipeline 576 Livestock Shelter Structure 590 Nutrient Management 580 Streambank and Shoreline Protection 578 Stream Crossing 472 Use Exclusion 614 Watering Facility 644 Wetland Wildlife Habitat Management

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
381 SILVOPASTURE **Establishing a combination of trees and compatible forages on the same acreage.**	● **Soil** – Improves soil health (soil organic matter, microbial habitat, aggregation, infiltration). Reduces erosion. ● **Water** – Reduces nutrient transport to surface water (encourages even manure distribution when done in conjunction with rotational grazing) and nutrient transport to groundwater (selection of trees and forages with high nutrient uptake). ● **Air** – Emissions of GHGs – Converting treeless pasture to silvopasture may accrue up to 800 lb woody biomass C/ac-yr. May initially reduce SOC through disturbance associated with installation; later gradually builds SOC. May reduce N_2O if trees are deep rooted and effectively recover soluble N that would otherwise leach or denitrify. ● **Plants** – Improves plant productivity and health (forages and trees) and enhances plant structure and composition through biodiversity. Especially beneficial to forage growth and quality in areas where full exposure to sun and wind would stress the forage species. ● **Animals** – Improves quality and season-long availability of forage, provides critical shade and shelter for livestock. Provides habitat for pollinators and other beneficial organisms	528 Grazing Management 315 Herbaceous Weed Treatment 516 Livestock Pipeline 512 Pasture and Hay Planting 595 Pest Management Conservation System 550 Range Planting 490 Tree/Shrub Site Preparation 612 Tree/Shrub Establishment 660 Tree/Shrub Pruning 645 Upland Wildlife Habitat Management 614 Watering Facility



Photo: USDA

NOTES

Silvopasture can provide new income and enterprise diversity for an operation.

This practice should be prioritized in the scenario where it is implemented on treeless cropland or grazing land. Converting forest or woodland to silvopasture entails thinning of trees which will cause loss of biomass C and some SOC at the outset. Once the forage is established, total sequestered C is stable or slowly increasing, and the other benefits listed are realized.

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
336 SOIL CARBON AMENDMENT **Soil Carbon Amendments are materials derived from plant materials or treated animal byproducts.**	● **Soil** – Improves soil health and fertility, builds stable soil organic matter, and can improve soil organism habitat and aggregate stability. ● **Air** – Emissions of GHGs – Can promote C sequestration (soil and biomass) by enhancing plant growth especially in semiarid regions. Use of organic soil amendments and fertilizers in lieu of soluble NPK alone can improve SOC stocks by 30%. Reduces GHG emissions when feedstocks are diverted from alternative waste streams. Compost improves nutrient cycling and may reduce N_2O emissions compared to poultry litter. Biochar mitigates N_2O emissions by 25-40%. Soil carbon amendments with low C:N ratio may increase N_2O emissions if tilled in. ● **Water** – Improves water quality through improved nutrient cycling, reduced fertilizer need, and less leaching. Promotes efficient use of naturally available moisture or irrigation water through improved water infiltration and soil water holding capacity.	317 Composting Facility 328 Conservation Crop Rotation 340 Cover Crop 342 Critical Area Planting 590 Nutrient Management 329 Residue and Tillage Management, No Till 345 Residue and Tillage Management, Reduced Till 384 Woody Residue Treatment



Photo: NSAC

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
585 STRIPCROPPING **Growing crops in systematic arrangement of strips in a field to reduce soil erosion, reduce particulate emissions into the air, and improve water quality.**  Photo: USDA NRCS	● **Soil** – Mitigates sheet, rill, and wind erosion. ● **Water** – Reduces transport of sediment, nutrients, and pesticides to surface water. ● **Air** – Emissions of GHGs – May sequester or retain more SOC than the same crop rotation but without alternating strips (e.g. entire field in corn, soy, wheat, and clover in years 1, 2, 3, and 4). Enhances the efficacy of the crop rotation in reducing soil erosion in sloping or wind-exposed fields. Soil erosion is a substantial factor in SOC losses from the eroding field and degradation of SOC in water- or windborne soil may be accelerated. May mitigate N_2O depending on crop species composition of the strips. ● **Plants** – Improves plant productivity and health (reduces exposure to wind-blown soil particles). Can reduce plant pest pressure if alternating strips of susceptible and non-susceptible crops harbor natural enemies of pests or slow the spread of pests and pathogens through the field.	328 Conservation Crop Rotation 340 Cover Crop 412 Grassed Waterway 590 Nutrient Management 595 Pest Management Conservation System 329 Residue and Tillage Management, No Till 345 Residue and Tillage Management, Reduced Till

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
612 TREE/SHRUB ESTABLISHMENT **Planting seedlings or cuttings, seeding, or creating conditions that promote natural regeneration.**  Photo: USDA NRCS	● **Soil** – Reduces soil erosion of all kinds. Builds soil health, soil organic matter, and soil organism habitat (microbial functional diversity). ● **Water** – Reduces transport of nutrients and other pollutants to surface and groundwater. ● **Air** –Trees intercept particulates and ozone precursors (dust, spray, drift, etc). Strategically placed tree/shrub plantings can protect organic production areas from pesticide spray and GMO pollen drift. Emissions of GHGs – Can sequester 800-1500 lb C (soil and biomass) per acre annually depending on species planted and soil/climate conditions. May reduce N_2O by 0.5-1.0 lb N_2O-N/ac-yr by reducing N input needs and intercepting excess soluble N. ● **Plants** – Improves plant productivity and health (mitigates microclimate, habitat for pollinators) and plant community structure and composition (diversity, native plants), reduces plant pest pressure. ● **Animals** – Provides habitat for wildlife and beneficial organisms. Provides livestock shelter. ● **Energy** – Conserves energy by providing shade for buildings.	472 Access Control 311 Alley Cropping 314 Brush Management 342 Critical Area Planting 655 Forest Trails and Landings 315 Herbaceous Weed Treatment 484 Mulching 595 Pest Management Conservation System 381 Silvopasture 490 Tree/Shrub Site Preparation 645 Upland Wildlife Habitat Management

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
633 WASTE RECYCLING **The on-farm agricultural use of nonagricultural waste by-products, or the off-farm nonagricultural use of agricultural waste by-products.**  Photo: USDA NRCS	● **Soil** – Improves soil health by building soil organic matter (when recycled material is composted or otherwise processed into a soil amendment to be used on or off farm). ● **Water** – Reduces transport of nutrients, pathogens, and other contaminants to surface or groundwaters (by stabilizing nutrients and exporting excess nutrients off farm when warranted). ● **Air** – Reduces emissions of airborne reactive nitrogen, particulate matter, greenhouse gases, and odors. Emissions of GHGs – If off-farm high-carbon organic byproducts are used to balance the N in manure, or if on-farm generated manure is sold or otherwise exported off farm, N_2O emissions may be mitigated. Use of recycled materials to amend soil can improve SOC sequestration. **NOTES** Benefits are maximized if a farm is taking and utilizing off-farm generated materials that would otherwise pose a resource/environmental concern, and/or the farm is exporting materials (e.g. manure) for beneficial off-farm use when staying on farm would pose a nutrient surplus/water pollution or other resource or environmental problem.	316 Animal Mortality Facility 317 Composting Facility 590 Nutrient Management 336 Soil Carbon Amendment 632 Waste Separation Facility 313 Waste Storage Facility 634 Waste Transfer 629 Waste Treatment

CONSERVATION PRACTICE STANDARD	RESOURCE CONCERNS ADDRESSED	SUPPORTING OR COMPANION PRACTICE STANDARDS
380 WINDBREAK/ SHELTERBELT ESTABLISHMENT AND RENOVATION **Single to multiple rows of trees and possibly shrubs planted in a linear fashion, established upwind of areas to be protected.**  Photo: USDA NRCS	● **Soil** – Greatly improves soil health within and near the windbreak planting. Reduces soil erosion, especially wind erosion. ● **Water** – Promotes efficient use of naturally-available moisture and irrigation water (by reducing evapotranspiration and retaining snow); traps and manages drifting snow, may reduce transport of nutrients to surface and groundwater (especially if windbreak species are deep rooted). ● **Air** – Protects production areas and farmsteads from particulate matter (dust), odors, and ozone precursors (pesticide spray drift). Can protect organic production areas from unintended exposure to pesticide spray and GMO pollen drift. Emissions of GHGs – Can sequester 1,280-1,430 lb C/ac-yr in soil and woody biomass within the area of the windbreak (typically 5% of the cropland area in which practice is implemented). May mitigate N_2O emissions especially within and near the windbreak planting. ● **Plants** – Enhances plant productivity and health by mitigating microclimate conditions and reducing wind damage ● **Animals** – Provides habitat for wildlife and beneficials. Provides shelter and shade for livestock. ● **Human** – Provides shelter and shade for farmers and farmworkers. May diversify enterprises and income streams if windbreaks provide marketable harvests.	328 Conservation Crop Rotation 340 Cover Crop 329 Residue and Tillage Management, No Till 345 Residue and Tillage Management, Reduced Tillage 336 Soil Carbon Amendment 490 Tree/Shrub Site Preparation 612 Tree/Shrub Establishment 660 Tree/Shrub Pruning 645 Upland Wildlife Habitat Management



EXAMPLE SCENARIOS

While individual conservation practices provide important benefits, the greatest gains in climate resilience, environmental quality, and farm profitability often come from implementing multiple practices together to address whole-farm resource concerns. The following scenarios illustrate ways farmers across different regions and production systems can combine NRCS conservation practice standards to fit their operations.

These scenarios are not prescriptive blueprints but rather examples of how conservation practices may work together towards a system-level goal.

Each approach will and should look different based on the region in which a farm operates and its priority resource concerns.

Whether farming annual row crops, managing specialty crop production, and/or raising livestock, these scenarios demonstrate pathways for making an operation more climate-friendly, resilient, and profitable. Producers should work with their local NRCS office or conservation partner to adapt these approaches to their specific farm context, resources, and goals.

ANNUAL CROPPING SYSTEM

Diversifying a cropping system can take several forms, including the structural variety of the crops grown, combining different plant families or varieties in one field (intercropping), rotating a wider range of crops over time, and other changes to the system.

For example, a standard corn-soy operation can extend its rotation with small grain crops in the cool season to keep the ground covered year-round. Research has shown both yields and profits were equal or higher for the longer rotations compared to the standard corn-soybean rotation, with a much lower environmental impact. Farmers can also implement a rotation that includes cover crops after each harvest.

In several USDA ARS Long Term Agroecological Research sites, organic crop rotations that include cover crop, cereal grain, and/or a perennial sod phase have accrued more soil organic carbon and supported more microbial activity and better nutrient cycling efficiency than a corn-soy rotation. Long rotations that include several years in pasture alternating with several years in annual crop with winter cover crops also have much lower erosion risk than corn-soy or wheat-fallow without cover crops.

When crops are selected carefully and well matched, intercropping and stripcropping - in which two or more production crops are grown simultaneously or in relay planting schemes within a field - can also result in greater total marketable yield, support natural enemies of pests, and mitigate losses if one crop fails. Relay cropping is an innovative approach which involves planting two or more cash crops in the same field at different times and managing them separately. Practices such as stripcropping, intercropping, and relay planting that combine crops of contrasting seasons and architectures can limit runoff and erosion and improve moisture retention by ensuring that the entire field is never left uncovered and exposed to the elements.

Adding livestock diversity into a system can reduce challenges like pests and diseases while allowing for nutrient cycling from livestock to soil and back to crop or forage species. Diversity within livestock systems, as with having chickens or small ruminants follow cattle in a pasture-based rotation, also provides multiple benefits, including pest suppression.

Diversifying systems with perennials offers the greatest benefits to soil health and water infiltration. Greater increases in structural, variety, and species diversity may be created with agroforestry systems: mixing trees and shrubs into annual and perennial grain, legume, and vegetable crops. By mixing some or all of the above systems across the landscape, the benefits of diversity increase substantially.

POTENTIAL CONSERVATION PRACTICE STANDARDS

328 Conservation Crop Rotation

327 Conservation Cover

332 Contour Buffer Strip

340 Cover Crop

386 Field Border

393 Filter Strip

422 Hedgerow Planting

590 Nutrient Management

595 Pest Management Conservation System

329 Residue and Tillage Management, No Till

345 Residue and Tillage Management, Reduced Till

391 Riparian Forest Buffer

336 Soil Carbon Amendment

585 Stripcropping

380 Windbreak/Shelterbelt Establishment and Renovation

BENEFITS

Increased rotational diversity benefits soil health and builds absorptive, high-capacity soils that are more resilient to the effects of climate instability, including heavy concentrated rainfall and periods of drought, and have more carbon sequestration potential. Diverse systems can also significantly reduce pests and diseases; increase crop production, quality, or stability of production; reduce needs for synthetic inputs; and offer more diverse income sources.



Photo: Jesse Frost & Hannah Crabtree

ADOPTING PERENNIAL PRACTICES

Perennial-based, diversified agricultural systems offer some of the most significant gains for soil health, nutrient retention and cycling, soil water infiltration, and water holding capacity. These include agroforestry, perennial pasture, perennial grains, and permaculture, which builds a highly diverse food-producing agroecosystem that mimics a locale's native plant community. Perennial vegetation provides soil coverage, protecting soils from the destructive effects of direct raindrop impact during heavy storms, as well as permanent root channels that enhance infiltration and storage to tide crops over drought periods and maintain adequate drainage and aeration during wet spells.

The addition of agroforestry practices to an agricultural system can buffer not just variation in precipitation, but also temperature and winds. Greater shade and shelter, carefully planned, can protect against both extreme cold events and extreme heat. Alley cropping, for example, is a practice where farmers can grow crops in 'alleys' between rows of trees and shrubs that can be selected regionally for their environmental benefits and their ability to provide an additional income source. Some examples of tree/shrub options include walnuts, chestnuts, hazelnuts, apples, elderberry, or timber, among others; and example alley crop options include vegetables, fruits, flowers, herbs, or forage crops.

Additionally, herbaceous and woody perennial conservation buffers can sequester carbon and create habitat for beneficial organisms as well as prevent wind damage to crops, improve water quality, and provide a barrier against chemical spray drift, unwanted pollen, and windborne pathogens, pests, and weed seeds.

For example, hedgerows and other flowering native habitats increase the presence of natural enemy insects and birds, making the farm more resilient to pest insects, rodents, and pest birds. Windbreaks use trees and shrubs to protect crops from wind damage and reduce soil erosion. Along water bodies, riparian buffers can help filter nutrients from runoff, trap sediment, cool water temperatures, and stabilize stream banks.

Perennial production systems can be managed to develop and evolve over time. For example, as trees and shrubs in an alley cropping system grow and mature, the alley crops may need to shift toward more shade-adapted species, and perhaps eventually to the understory of a forest farming system. In addition, as a locale's temperature and rainfall patterns change due to climate impact, perennial crops and cultivars better adapted to new conditions can be introduced as species that can no longer thrive are phased out.

POTENTIAL CONSERVATION PRACTICE STANDARDS

311 Alley Cropping

332 Contour Buffer Strips

342 Critical Area Planting

386 Field Border

393 Filter Strips

379 Forest Farming

412 Grassed Waterways

422 Hedgerow Planting

512 Pasture and Hay Planting

391 Riparian Forest Buffer

390 Riparian Herbaceous Cover

612 Tree/Shrub Establishment

380 Windbreak/Shelterbelt Establishment and Renovation

BENEFITS

Perennial systems offer significant climate benefits through carbon sequestration. The permanent root systems and canopy cover can help improve water-use efficiency and moderate microclimates. Perennials additionally improve biodiversity, support natural pest control, reduce erosion from wind and water, filter runoff to improve water quality, and create diversified income streams.



Photo: Sharing Our Roots

LIVESTOCK PRODUCTION

Improving the environmental benefits of livestock production may include implementing advanced grazing management systems, integrating woody perennials into grazing systems, and, for operations where livestock spend part of their time indoors, taking on alternative manure management strategies.

In a well-managed rotational grazing system, where livestock are periodically moved to fresh paddocks to allow pastures to regrow, feed costs decline and animal health improves. Advanced grazing management systems, including management intensive rotational grazing, mob grazing, and adaptive multi-paddock grazing, can be especially effective at sequestering carbon, optimizing manure distribution, and keeping livestock out of streams and ponds.

Introducing trees may enable even higher levels of carbon sequestration without decreasing livestock productivity. A cattle operation can transition to silvopasture by planting tree rows in open pasture, choosing trees, forage, and grazing livestock that complement one another to improve production. When well managed, trees can provide an additional income source, and shade for the animals; and livestock and forage crops can promote nutrient cycling and nitrogen fixation to promote tree growth.

For operations where livestock spend part of their time indoors, and there is manure accumulation, moving away from liquid manure handling can also mitigate a livestock operation's environmental footprint. Transitioning from storing liquid manure in lagoons or pits where anaerobic conditions promote methane emissions to solid manure handling and storage can reduce volatile organic compounds and run-off. Examples of practices include flush to scrape conversion, solid separation technologies, open solar drying or composting of manure onsite, compost bedded pack barns, and transitioning to pasture-based management. These low-tech and lower cost alternatives to digesters can benefit operations of all sizes.

Additionally, composting manure with bedding or other organic carbon sources can provide a great contribution to resilience by enhancing soil health benefits of the resulting soil amendment and minimizing environmental risks.

POTENTIAL CONSERVATION PRACTICE STANDARDS

513 Annual Forages for Grazing Systems

317 Composting Facility

382 Fence

511 Forage Harvest Management

528 Grazing Management

516 Livestock Pipeline

576 Livestock Shelter Structure

512 Pasture and Hay Planting

550 Range Planting

390 Riparian Herbaceous Cover

381 Silvopasture

336 Soil Carbon Amendment

614 Watering Facility

633 Waste Recycling

632 Waste Separation Facility

313 Waste Storage Facility

BENEFITS

Advanced grazing management can promote increases in soil organic matter, water holding capacity, and nutrient cycling. The climate benefits of silvopasture are also among the strongest of any agricultural system for carbon sequestration. Livestock benefit from natural shelter and pasture productivity, and trees can help reduce runoff, improve water infiltration, and provide diversified income. Composting manure can reduce methane emissions and nutrient pollution, improving air and water quality.



Photo: C. J. Isbell of Keenbell Farm

ORGANIC MANAGEMENT

Organic management is a principles-based **holistic farming system that promotes and enhances biodiversity, resource cycling, and soil health and biological activity**. Organic systems use site-specific management; maintain soil fertility through diverse rotations, cover crops, and applications of plant and/or animal materials; manage weeds, pests, and diseases through cultural, physical, and biological controls; and do not use genetically modified seed or synthetic pesticides or fertilizers. While the National Organic Program (NOP) develops the rules and regulations for all USDA organic production and products, producers can adopt practices that are intrinsic to organic production by using NRCS conservation programs to improve an operation whether or not they choose to seek USDA organic certification.

Adoption of organic systems that include multiple stacked practices, such as organic amendments, diversified rotations, and cover crops, as well as not using synthetic inputs, can enhance soil organic carbon (SOC) stocks by 35 percent over time. Different practices and crops build SOC in different and complementary ways which may result in greater stability and quality of SOC and a wider range of soil biological functions than would result from single practices. Effects of organic systems on nitrous oxide emissions vary, however, from significant mitigation to large increases that may negate SOC gains, so careful nutrient management that is well timed with crop uptake is necessary.

Using biological forms of fertilizer, such as compost, animal manures, and legume cover crops, builds soil organic matter (SOM) and improves nutrient cycling and water holding capacity, and can reduce annual nitrate leaching losses by half compared to soluble fertilizers. Fully composting manure before applying further enhances soil carbon retention and biological activity.

To keep pests in check, producers may work through a strategy of prevention, avoidance, monitoring, and suppression, a core framework used in integrated pest management to address pest and environmental impacts. Adding perennials can help, especially flowering species that provide habitat for pollinators and natural enemies of pests while building soil health. Trees and shrubs can provide barriers and buffer zones to protect fields from pesticide and pollen drift and runoff from neighboring conventional operations.

Integrating livestock can also cycle nutrients and reduce off-farm inputs, aid in pest and weed control, and improve SOM and water infiltration. Organic management requires livestock and poultry to have year-round outdoor access and ruminants to receive a minimum 30% of their Dry Matter Intake (DMI) from pasture, improving livestock feed and forage balance.

POTENTIAL CONSERVATION PRACTICE STANDARDS

311 Alley Cropping

513 Annual Forages for Grazing Systems

317 Composting Facility

327 Conservation Cover

328 Conservation Crop Rotation

340 Cover Crop

386 Field Border

393 Filter Strip

528 Grazing Management

422 Hedgerow Planting

325 High Tunnel System

484 Mulching

590 Nutrient Management

595 Pest Management Conservation System

345 Residue and Tillage Management, Reduced Till

391 Riparian Forest Buffer

390 Riparian Herbaceous Cover

381 Silvopasture

336 Soil Carbon Amendment

585 Stripcropping

612 Tree/Shrub Establishment

380 Windbreak/Shelterbelt Establishment and Renovation

BENEFITS

Organic management builds soil organic matter, which improves soil health, aggregate stability, and water holding capacity, reducing erosion and runoff and increasing resilience to heavy rain and drought. Diversified organic systems support pollinators, wildlife, and beneficial soil organisms and, when livestock are integrated, can improve forage balance and on-farm nutrient cycling. Producers can also manage their cost of inputs by eliminating synthetic pesticides and fertilizers and reducing organic fertilizer applications as soil health and nutrient cycling improve, additionally reducing greenhouse gas emissions and keeping those inputs out of surface and groundwater.

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CPS 311 Alley Cropping

"Emissions of GHGs – Sequesters 800-1,200 lb C/ac-year in soil and woody biomass, may reduce N_2O by 0.5-1.0 lb N_2O N/ac-yr by reducing N input needs and intercepting excess soluble N."

References:

Biardeau et al., 2016 (COMET Farm estimate 1020 lb C seq/ac-yr).

Bazrgar et al., 2024 (woody biomass C seq. 270-670 lb C/ac-yr – trials in Ontario, Canada where growing season is shorter than most of the US)

Mayer et al., 2022 (SOC sequestration surface to 40 cm ~440 lb/ac-yr, meta-analysis)

Beillouin et al., 2023 [SOC stocks +21% (95% confidence interval +14 to +30%)]

Thevathesan & Gordon, 2004 (N_2O mitigation – they estimated 0.7 lb/ac-yr).

De Stefano & Jacobson, 2017; Shi et al., 2018 (showing that C sequestration by trees and shrubs extends 60-100 cm into the soil profile; thus, SOC data based on the top 20-30 cm may underestimate total SOC sequestration under agroforestry practices. Also see Notes under Conservation Cover).

Note: Beillouin et al. (2023) conducted an extensive global second-order meta-analysis of SOC sequestration through a wide range of practices and systems, and expressed results in relative (%) differences in SOC stocks (lb/ac) with versus without the practice. The estimate for alley cropping is +20%, and because deep-rooted tree crops add C throughout the top 100 cm of the soil profile, and total SOC stocks in mesic (moderate to high rainfall) climates are typically about 100 Mg/ha (45 tons/ac), a 20% increase ~9 tons/ac, if it takes place over a 40-year maturation period of the alley crop is about 450 lb/ac in SOC alone. Estimates of annual SOC accrual rates for this and other practices are based on statistics from Beillouin et al (2023) interpreted in conjunction with other research findings reported in lb SOC/ac. For alley crops, Mayer et al (2022) estimated SOC accrual at 437 lb/ac-yr, close to the Beillouin et al (2023)-derived estimate.

CPS 317 Composting Facility

"Less GHG emissions than alternative fates of materials (lagoon or static dry stack for manure, landfill or burn pile for yard trimmings, food waste, fine fuel removal from forests, etc.) May enhance soil and plant biomass carbon sequestration when compost is applied to agricultural lands."

References:

Pattey et al., 2005 (GHG emissions from manure management lagoon > solid storage > composting).

Reeve et al., 2012, 2023; Ryals & Silver, 2013 (compost applications can build SOC beyond the C in the compost itself by enhancing plant growth, root biomass, and rhizodeposition).

Bhowmik et al, 2016; Krause et al., 2022 (compost builds substantially more SOC than uncomposted manure or poultry litter).

CPS 327 Conservation Cover

"Substantial carbon sequestration in soil and biomass, estimated at 780 lb/ac-yr in COMET Farm."

Main reference:

Biardeau et al., 2016.

Additional relevant references:

Beillouin et al. 2023, Mosier et al., 2021; andYang et al., 2019.

Notes: Fewer studies on total C sequestration have been conducted for herbaceous perennial plantings than for agroforestry. Biardeau et al. (2016) cited 780 lb C/ac-yr, and Beillouin et al (2023) estimated that converting cropland to grassland yields a net cumulative increase in SOC stocks of 26%.

Most studies of management factors in SOC accrual focus on the top 4 to 12 inches (10-30 com) of the soil profile, which can capture most SOC sequestration from practices like conservation tillage, cover cropping, and improved rotations focused on annual crops, but may miss a substantial fraction of SOC accrual from both herbaceous and woody perennials, whose deeper roots can build SOC to 60-100 cm (24-39 inches) in the soil profile (De Stefano & Jacobson, 2017; Mosier et al., 2021; Shi et al., 2018;Yang et al., 2019). Thus, a 26% increase in SOC from converting annual cropland to conservation cover or other herbaceous perennial conservation planting (i.e., grassland, Beillouin et al., 2023) in a mesic climate could represent 10 tons C/ac or more, which is equivalent to 25 years of sequestration at the COMET Farm estimated rate.

CPS 328 Conservation Crop Rotation

"SOC sequestration may vary from negligible to ~300 lb/ac-yr depending on how it is implemented."

References:

Biardeau et al., 2016 (COMET Farm 120 lb/ac-yr).

Beillouin et al., 2023 (SOC increased 6.5% with a 95% confidence interval of -1 to +14% based on 300 paired comparisons – just short of statistical significance).

West & Post, 2002 (180 lb/ac-yr, continues up to 40 years before plateau).

Prairie et al., 2023 (when the rotation entails "crop intensification" – increased number of cash and cover crops and duration of living roots – SOC at surface-20 cm (8in) increases 12%; adding a deep-rooted perennial also builds SOC below 20 cm).

CPS 332 Contour Buffer Strips

"Area under the buffer may build ~780 lb SOC + biomass C/ac-yr (from COMET Farm 2016)"

Reference:

Biardeau et al., 2016. See notes under CPS 327 Conservation Cover.

CPS 340 Cover Crop

"Basic cover cropping practices add ~210 lb SOC/ac-yr, reaching a plateau at about 12% increase in SOC stocks."

"High biomass intensive cover cropping/continuous living cover can sequester 300-350 lb SOC/ac-yr and ultimately enhance SOC stocks by 30%.

"Tilling in a cover crop may increase N_2O emissions by 1-3 lb/ac-yr (negates 129-387 lb/ac C sequestration), especially if it is a legume or other low C:N cover crop.

"Tilling any cover crop at the same time as manure, poultry litter, or synthetic N is applied can cause N_2O releases of 9 lb/ac or more (negates the C sequestration)."

References:

Beillouin et al., 2023 estimated that cover crops enhance SOC stocks +12% based on 3,000 comparisons. Studies by Peng et al., 2023; Prairie et al., 2023; Sprunger et al., 2020; and Weber et al., 2024 gave similar estimates. Different cover crop functional groups have different and complementary effects on SOC (Zhang et al., 2022) and grass-legume mixes build more SOC (+22%) than monocultures (+11-13%) (Muhammad et al., 2019). Cover crops must attain at least 900 lb/ac aboveground biomass to build SOC, and regular use of long-duration cover crops that attain at least 6,250 lb/ac can boost SOC stocks by up to 30% (Liang et al., 2021; McClelland et al., 2021a&b; Schipanski et al., 2024).

Biardeau et al., 2016 (210 lb SOC/ac-yr sequestered, COMET Farm). Other estimates of cover crop SOC sequestration rates range from 195 to 295 lb/ac-yr (Fargione et al., 2018; Peng et al., 2023; Qin et al., 2023; Weber et al., 2024) and one outlier estimate at 412 lb/ac-yr (McClelland et al., 2021b).

Terminating an all-legume cover crop by tillage typically adds about 1.5-2 lbN_2O-N/ac-yr to the GHG footprint (Han et al., 2017; Lugato et al., 2018), and tilling in any cover crop with manure, poultry litter, or other N fertilizer can boost emissions by 9 lbN_2O-N/ac-yr or more (Baas et al., 2015; Davis et al., 2019; Li et al., 2009; Saha et al., 2021). Cover crop N_2O emissions can be mitigated by growing grass-legume mixtures and terminating any low C:N cover crop with roller-crimper or other no-till methods (Muhammad et al., 2019).

CPS 342 Critical Area Planting

"Sequesters soil and biomass carbon at rates similar to those cited in COMET Farm for other herbaceous and woody perennial plantings (780 and 1020-1500 lb/ac-yr, respectively)."

Reference:

Biardeau et al., 2016.

CPS 386 Field Border

"Can sequester ~780 lb C/ac-yr in soil and perennial biomass (roots, woody shrubs if these are included) within the field border area."

"Planting a diverse field border of several functional groups (warm/cool season, grass, legume, other forbs, shrubs) may sequester more carbon in soil and root biomass than a monoculture such as switchgrass or miscanthus alone."

References:

Biardeau et al, 2016 (COMET Farm estimate).

Yang et al., 2019 (plantings of 8 or 16-component perennial prairie mixes in a degraded cropland soil sequestered soil and root biomass C two to three times as fast as either a single species planting or natural secondary succession).

CPS 393 Filter Strip

"Sequesters ~780 lb C/ac-yr in soil and grass roots within the filter strip area."

Reference:

Biardeau et al., 2016 (COMET Farm estimate).

CPS 379 Forest Farming

"Conversion of treeless cropland to forest farming sequesters at least 800-1,200 lb C/ac-year in soil and woody biomass, and it may reduce N_2O by 0.5-1.0 lb N_2O-N/ac-yr by reducing N input needs and intercepting excess soluble N."

References:

Biardeau et al., 2016 (COMET Farm estimate 1,020 lb/ac-yr).

Beillouin et al., 2023 (20% increase in SOC stocks from converting treeless cropland to agroforestry; 12% loss in SOC from converting forest to agroforestry; 32% SOC loss upon converting forest to annual cropland).

Bazrgar et al., 2024; Possu et al., 2016; Tufekcioglu et al., 2003; Udawatta et al., 2011 (Estimates of woody biomass C sequestration rates under other agroforestry practices range from about 440 lb/ac-yr to as high as 2,000 to 12,000 lb/ac-yr).

Shi et al. 2018 global meta-analysis found larger increases in SOC and woody biomass C in "home gardens" (small scale forest farming) than for alley crops, windbreaks or silvopasture. Based on 47 comparisons, home garden SOC was 32% higher than treeless areas, representing an increase of ~5 tons SOC/ac, and aboveground woody biomass was estimated at 17.8 tons/ac.

Schoeneberger et al., 2012, Thevathesan and Gordon, 2004, and Tufekcioglu et al., 2023 (Agroforestry systems reduce potential N_2O emissions through reduced N input needs, improved N cycling and N use efficiency, and recovery of soluble N by deep-rooted trees and shrubs. The 0.5-1.0 lb N_2O-N/ac-yr mitigation estimate is based on alley cropping research by Thevathesan and Gordon, 2004. Since forest farming provides greater tree canopy and multistory plant community structure, this may be a conservative estimate of N_2O mitigation).

CPS 412 Grassed Waterway

"Sequesters ~780 lb C/ac-yr in soil and grass roots within the waterway planting."

Reference:

Biardeau et al., 2016 (COMET Farm estimate).

CPS 528 Grazing Management

"Findings on net C sequestration for rotational grazing vary widely from no net GHG mitigation up to 1 to 2 tons SOC/ac-yr for the first several years after conversion from either cropland or unmanaged grazing to sound, regionally appropriate, rotational grazing or other advanced grazing management. Timely rotation among paddocks and strategic placement and movement of shade structures and watering stations to improve manure distribution can minimize N_2O "hotspots" related to manure accumulations."

References:

Machmuller et al., 2015; Stanley et al., 2018; Teague et al., 2016; Wang et al., 2015 (reports of SOC sequestration rates upon conversion either from annual cropland or unmanaged grazing to management-intensive rotational grazing > 2,000 lb/ac-yr for 5-10 years after conversion).

Prescott et al., 2021 (optimally timed rotational grazing with new paddocks opened near the end of forage rapid-growth phase enhances root exudation and MAOC formation).

Byrnes et al., 2018 (meta-analysis of 64 studies found that rotational grazing does not build SOC compared to ungrazed grassland, but it does avoid the SOC losses and mitigate the compaction resulting from continuous grazing).

Booker et al., 2013; Morgan et al., 2010; Wang et al., 2016 – in semiarid regions, estimated SOC accruals are much more gradual under best grazing management (which must be adapted to region) – ranging from 60-265 lb/ac-yr, though, when maintained over an 80 year period, can accrue significant SOC gains (2.6 tons/ac).

Mosier et al., 2021. (In a comparison study of five paired comparisons of adaptive multipaddock grazing (AMP, similar to MIG) versus nearby continuous grazed pastures in KY, AL, TN, MS, the AMP pastures sequestered an average of 4 tons SOC/ac in a 9-29 year period).

Manale et al., 2016; Richard and Camargo, 2011 (grassfed cattle emit more enteric CH4 than grainfed animals because the former diet is higher in fiber and lower in protein).

Manale et al., 2016; Ominski et al., 2001; Stanley et al., 2018; Wang et al., 2015 (improving forage quality through optimum grazing management can reduce ruminant enteric CH4 emissions by 30-50% compared to lower quality pasture).

Luo et al., 2017 (manure accumulations in pastures, e.g., along fencelines or near watering stations or shady areas in a continuously grazed pasture become N_2O hotspots that can be mitigated by rotational grazing).

CPS 422 Hedgerow Planting

"Sequesters 1,000 lb or more C/ac-yr in soil and woody biomass within the hedgerow planting. May help mitigate N_2O by taking up soluble N."

References:

Biardeau et al., 2016 (COMET Farm estimate is 1,020 lb/ac-yr).

Beillouin et al., 2023 (SOC stocks increase 17% under hedgerows).

Mayer et al, 2022 (meta-analysis, 26 comparisons showed SOC gains of 535 lb/ac-yr in top 40 cm = 16 inches).

Biffi et al., 2025 (study of 46 hedgerows in the United Kingdom showed initially rapid SOC gains, then plateau at net increase of 40% ~ 18 tons SOC/ac compared to adjacent grassland).

CPS 484 Mulching

"May enhance SOC sequestration to some degree, especially if plant growth and biomass are benefitted."

Reference:

Biardeau et al., 2016 (COMET Farm estimate of 180 lb C/ac-yr net mitigation for the mulching practice).

Mkhabela et al., 2008; Yarwood, 2016; Grados et al., 2022 (no-till usually has small and variable impacts on N_2O emissions, but can increase N_2O in wet conditions if the no-till practice itself or a heavy roller-crimped cover crop slows soil drying. Similar considerations may apply to mulching with organic materials – or with plastic film if it retains excess moisture and creates conditions favorable to denitrification and N_2O emissions).

CPS 590 Nutrient Management

"Estimates have net GHG benefits (N_2O mitigation, in CO2-C equivalents) at just 90 lb/ac-yr for "nutrient management - improved N fertilizer" and standard "4Rs" nutrient management, and 1,080 lb/ac-yr if all N can be derived from soil mineralization. Reductions in application rates of synthetic N also reduce the embodied GHG emissions in fertilizer manufacture (~1.2 lb CO2-C per 1 lb fertilizer N). Avoiding excess soil soluble N and relying on slower-release organic N sources can enhance formation of stable SOC."

References:

Biardeau et al., 2016 (COMET Farm estimates of net GHG mitigation are 90 lb/ac-yr from "nutrient management – improved nitrogen fertilizer" and 1,080 lb N/ac-yr for "replacement of synthetic nitrogen fertilizer with soil-derived NI").

Baas et al., 2015; Davis et al., 2019; Eagle et al., 2017; Han et al., 2017; Li et al., 2009 (N_2O emissions increase exponentially as applied N rates increase beyond crop need; heavily N fertilized annual crops account for most of the N_2O in a crop rotation. Emissions from conventionally or organically fertilized heavy N feeders can range from 2 to 10+ lb N_2O-N/ac-yr, which is equivalent in global warming potential to conversion of 258-1,290 lb SOC/ac-yr into CO2.)

Berthrong et al., 2013; Franzluebbers, 2018a; Franzluebbers et al., 2018a, 2018b, and 2020; Kloot, 2018; Spargo et al., 2011. (As soil biological activity, SOM levels and quality, and overall soil health improve, the soil's capacity to provide crop-available N through mineralization of soil organic N increases so that the actual amount of fertilizer N needed to sustain crop yields declines to 50% or less of standard recommendations. In a multisite study in the southeastern US (mostly Ultisols, not known for their high fertility), the Economic Optimum Nitrogen Rate (EONR) for corn grain, corn silage, and fescue forage declined to zero on the most biologically active soils – including one-third of study sites. Since the "right rate" of the 4Rs approach to CPS 590 Nutrient Management is based on Land Grant University (LGU) recommendations based on crop and yield goal, reducing actual N application rates to the EONR rather than LGU recommendations could substantially curb N_2O emissions).

Franzluebbers, 2018b, 2022 (Development, testing, and refinement of a 3-day soil respiration laboratory protocol for estimating soil N mineralization and thereby EONR.)

Schlesinger, 2000 (Manufacture of 1 lb synthetic fertilizer N emits about 1.2 lb CO2-C. Thus, reducing fertilizer N applications by 50 lb/ac would save about 60 lb CO2-C/ac.).

Bhowmik et al., 2016, 2017; Bowles et al., 2015; Krause et al., 2022; Prescott et al., 2021 (Slow release sources of N such as finished compost (C:N~15-20:1) sustain significantly higher microbial activity and build more active and stable SOC than concentrated sources like poultry litter (C:N ~7:1), bat guano, or synthetic soluble N fertilizers).

Organic Management

"A global meta-analysis indicates that adoption of organic systems that include multiple stacked practices - organic amendments, diversified rotations, cover crops, etc., as well as non-use of synthetics - can enhance SOC stocks by 35% over time. Different practices and crop functional groups build SOC in different and complementary ways which may result in greater stability and quality of SOC than from single practices. Effects of organic systems on N_2O emissions vary from significant mitigation to large increases that may negate SOC gains. Careful N management and further research into N_2O mitigation in organic systems are needed."

References:

Beillouin et al., 2023; Second-order global meta-analysis on impacts of practices and systems on SOC, including some 25,000 studies. Only a few studies focused on systems of multiple or stacked practices, but there were sufficient comparisons of organic vs conventional systems in which the former "involve varying degrees of organic amendments and crop diversification, among other practices" to provide an estimate of 35% increase in SOC stocks (95% confidence interval +11% - +64%) in organic systems. The use of organic amendments and nutrient sources accounted for 29-34% SOC increase, and thus appears to be the main driving factor in the SOC benefits of organic agriculture; cover cropping alone increased SOC stocks by just 12% and crop rotation 6% (not statistically significant).

Brennan and Acosta-Martinez et al., 2017; Crystal-Ornelas et al., 2021; Hurisso et al., 2016; Prairie et al., 2023 (living plant cover, organic amendments, and reduced tillage have different and complementary impacts on soil health. For example, in an organic vegetable cropping systems study in Salinas, CA, compost applications drove increases in total SOC while cover crops drove increases in microbial biomass).

Prescott et al., 2021; Zhang et al., 2022 (legume cover crops with a low C:N ratio promote microbial growth and formation of mineral associated organic carbon (MAOC, long-term sequestration) while grasses with a higher C:N ratio promote formation of occluded particulate organic carbon (oPOC, short term sequestration). Mixtures of cover crops benefit a wider range of soil health functions than single species covers).

Baas et al., 2015; Bhowmik et al., 2016; Bowles et al., 2015; Davis et al., 2019; Eagle et al., 2017; Han et al., 2017; Li et al., 2009; Lugato et al., 2018; Lussich et al., 2024; Muhammad et al., 2019; Young et al., 2022 (soil N_2O emissions are favored by a combination of high microbial activity, ample decomposable organic matter such as manure or crop residues, moderate to high soluble N, and reduced oxygen levels; they increase exponentially as soluble N levels increase beyond crop N needs. Organic soil health practices provide the high microbial activity and decomposable organic residues, and N must be managed carefully to avoid high N_2O emissions. Tilling an all-legume cover crop into the soil typically adds ~ 2 lb/ac to the season's N_2O emissions, and tilling any cover crop with manure or poultry litter at the same time can release 10 lb of N_2O-N/ac, negating some 1,290 lb SOC/ac sequestration. The intense microbial activity promoted by incorporation of cover crop residues + manure can lower O2 levels sufficiently to promote N_2O emissions even when the soil is not excessively wet. N_2O emissions can be mitigated by planting grass-legume mixes, terminating cover crops no-till, and never tilling manure and cover crop residues into the soil together. Relying on compost and other slow-release N sources rather than concentrated materials like poultry litter can improve the soil microbial capacity to cycle N and limit N_2O formation. More research is needed to fine-tune strategies to manage N and mitigate N_2O emissions in organic systems).

CPS 512 Pasture and Hay Planting

"Converting cropland to pasture can sequester substantial C in soil and biomass, potentially ~780 lb/ac-yr."

Reference:

Biardeau et al., 2016 (The COMET Farm estimate for "forage and biomass planting (= former name for CPS 512) full conversion" is just 210 lb C/ac-yr, which conflicts with other findings, unless this applies to renovation of an existing pasture that has become degraded or depleted of desirable species. However, conversion of cropland to pasture and hay planting would be expected to sequester C at rates similar to other herbaceous perennial conservation plantings estimated by COMET Farm at 780 lb/ac-yr).

Yang et al. (2019) found that diverse plantings that include legumes, other forbs, and both C3 (cool season) and C4 (warm season) grasses build SOC + root biomass C two to three times as fast as either a monoculture planting or natural secondary succession on abandoned cropland. Thus, planting a diverse mix of adapted species to convert cropland to pasture should sequester carbon at the COMET Farm rate cited for herbaceous conservation plantings.

CPS 595 Pest Management Conservation System

"Pesticides contain ~3-11 lb embodied CO2-C per 1 lb active ingredient in their manufacture. This does not include the embodied CO2-C in inert ingredients used to formulate pesticides for field application, the composition of which is often undisclosed. In addition, some pesticides adversely affect soil microbiomes in ways that can compromise the soil's capacity to sequester carbon or regulate (mitigate) nitrous oxide formation."

References:

Audsley et al., 2009; Sharma et al, 2023 (CO_2-C embodied in pesticide manufacture).

Gunstone et al. 2021; Klein, 2019; Pelosi et al., 2014; Puissant et al., 2021; Vahter et al., 2022; Walder et al., 2022 (all major classes of pesticides used at label rates can adversely affect all major taxonomic groups of soil organisms, often to a greater degree than the impacts of conventional tillage. Soil functions compromised by pesticide exposures may include capacity to form stable SOC, cycle N efficiently, and limit N_2O formation).

Atwood et al., 2018; Nettles et al., 2016 (seed treatments with neonicotinoids or fungicides have especially strong impacts on the soil microbiome).

Joly et al., 2012: Tejada et al., 2009 (applying two herbicides with different modes of action can synergistically magnify and prolong their impacts on the soil microbiome).

Atthowe, 2010; Merrington et al., 2002; Singh et al., 2015 (NOP-allowed pesticides like azadirachtin insecticide, acetic acid herbicide, and copper-based fungicides can also adversely affect the soil microbiome, which is why NOP requires high-level preventive and biological IPM and use of NOP allowed pesticides only when these other methods prove insufficient).

CPS 550 Range Planting

"SOC and biomass C accrue only slowly in semiarid or arid rangeland, but the gradual increases realized from range planting and best grazing management (60-100 lb C/ac-yr) may continue for several decades."

References:

Booker et al., 2013; Morgan et al., 2010; Wang et al., 2016 (in rangeland, most of which is arid to semiarid, SOC sequestration is limited by abiotic factors so that "best grazing management" including species selection in planting builds SOC only slowly. However, 80 years of improved rangeland management has built SOC by 2.6 tons/ac, or about 65 lb/ac-yr, over a wide area in the Great Plains).

Yang et al., 2019 (functionally diverse mix of 8-16 species of native prairie species built SOC and root biomass C two to three times as fast as monoculture or old-field succession).

CPS 329 Residue and Tillage Management, No Till

"Sequesters SOC at ~270 lb/ac-yr for the first 10-15 years, reaching a plateau at ~10% increase in SOC stocks. Near-surface SOC accrued through no-till is readily lost with even a single tillage pass (often needed every few years to manage weeds or relieve compaction). Effects on N_2O are variable – can mitigate if legume cover crops are terminated no-till; can increase slightly if heavy residue keeps soil too wet."

References:

Biardeau et al., 2016 (COMET Farm, 270 lb/ac-yr), Beillouin et al., 2023 (+9.3% cumulative based on 7,000 paired comparisons). West and Post, 2002 (cites higher rate of 510 lb/ac-yr but plateau after 10-15 years).

Baker et al., 2007; Grandy et al., 2006; Grandy and Robertson, 2007, Kane, 2015 (most of SOC accrual from no-till by itself is in top 10 cm, and much of this is readily lost upon a single tillage pass).

Muhammad et al., 2019 (Cover crops terminated no-till tend to mitigate soil N_2O emissions while tilling in legume cover crops boosts N_2O emissions).

Mkhabela et al., 2008; Yarwood, 2016; Grados et al., 2022 (No-till usually has small and variable impacts on N_2O emissions, but can increase N_2O in wet conditions if the no-till practice itself or a heavy roller-crimped cover crop slows soil drying).

CPS 345 Residue and Tillage Management, Reduced Till

"Accrues SOC at slower rates (110-180 lb/ac-yr) than no-till (~270 lb/ac-yr) but attains similar plateau (10% increase in SOC stocks). Improves microbial activity and formation of stable SOC over either no-till or full inversion tillage. Effects on N_2O are minor unless the tillage operations incorporate legume green manure or N fertilizer + any cover crop."

"Reduced tillage (non-inversion full field tillage to depths of 5-15 cm = 2-6 inches) maintains twice the microbial biomass as either full tillage (moldboard plow + disk) or continuous no-till. Microbial activity plays a central role in transforming residues and root exudates into mineral-associated organic carbon (MAOC), the most stable form of SOC. Terminating cover crops by roller-crimper to avoid N_2O emissions from mixing legume residues into the soil can be part of an overall reduced-tillage system (rotational no-till - often practiced by organic farmers)."

References:

Biardeau et al., 2016 (COMET Farm estimate 110 lb/ac-yr). Beillouin et al., 2023 [based on limited number of comparisons, reduced till enhances SOC stocks by ~12% (95% confidence interval + 0.1 to + 24%, barely significant)].

Morugán-Coronado et al., 2022 (reduced tillage maintains nearly double the bacterial and fungal biomass as either full till or no-till). Prescott et al., 2021 (review article demonstrating central role of microbial activity in formation of MAOC). Bhowmik et al., 2017; Hurisso et al., 2016; Krause et al., 2022 (microbial biomass and soil respiration are positively correlated with SOC sequestration).

Han et al., 2017; Lugato et al., 2018 (tilling legume cover crop residues into the soil may boost N_2O emissions by 1.5-2 lbN_2O-N/ac-yr). Baas et al., 2015; Davis et al., 2019 (tilling in any cover crop with manure or other N fertilizer can boost emissions by 9 lbN_2O-N/ac-yr or more).

Muhammad et al., 2019 (cover crop N_2O emissions can be mitigated by growing grass-legume mixtures and terminating any low C:N cover crop with roller-crimper or other no-till methods).

CPS 391 Riparian Forest Buffer

"Sequesters ~1,500 lb C/ac-yr or more in soil + woody biomass within the buffer area, may reduce N_2O emissions by intercepting and taking up soluble N."

References:

Biardeau et al. 2016 (COMET Farm estimate).

Tufekcioglu et al., 2003; Udawatta & Jose, 2011 (woody biomass C sequestration estimated at 2,300-2,600 lb/ac-yr. Riparian forest stands tend to be thicker than alley crop, forest farming, or silvopasture plantings).

Schoeneberger et al., 2012; Tufekcioglu et al., 2023 [Perennial riparian buffer intercepts soluble N leaving adjacent fields or pastures, thereby reducing both direct (on-site) and indirect (off-site) N_2O emissions].

CPS 390 Riparian Herbaceous Cover

"Can sequester ~780 lb C/ac-yr in soil and perennial biomass within the area planted to herbaceous cover. Can reduce N losses to waterways and thereby reduce off-site N_2O formation."

References:

Biardeau et al. 2016 (COMET Farm estimate).

Schoeneberger et al., 2012; Tufekcioglu et al., 2023 [Perennial riparian buffer intercepts soluble N leaving adjacent fields or pastures, thereby reducing both direct (on-site) and indirect (off-site) N_2O emissions.]

CPS 381 Silvopasture

"Converting treeless pasture to silvopasture may accrue up to 800 lb woody biomass C/ac-yr. May initially reduce SOC through disturbance associated with installation; later gradually builds SOC. May reduce N_2O if trees are deep rooted and effectively recover soluble N that would otherwise leach or denitrify."

References:

Beillouin et al., 2023 [26% increase in SOC from conversion of treeless pasture to silvopasture, based on 250 comparisons; versus 20% increase in SOC for other agroforestry practices (hedgerow, alley cropping) on previously treeless cropland, based on 1500 comparisons. However, thinning of existing forest for silvopasture may entail a net loss of biomass C and soil C].

Biardeau et al., 2016 (did not give COMET Farm estimate for silvopasture; but gave an estimate of 1,020 lb/ac-yr for alley cropping and hedgerow).

Greene et al., 2023; Orefice et al., 2025 (woody biomass in nut trees or timber trees planted for silvopasture estimated to accrue 800 lb woody biomass C/ac-yr.).

Mayer et al., 2022; Orefice et al., Shi et al., 2018. (Conversion of open pasture to silvopasture may not sequester as much additional soil carbon because grassland itself has a much higher starting SOC stock than cropland).

Beillouin et al., 2023; De Stefano & Jacobson, 2017; Mayer et al., 2022 (The soil disturbance that a tree planting operation entails may cause an initial loss of SOC followed by accruals as the trees become established).

Thevathesan & Gordon, 2004 (a study on N_2O mitigation through alley cropping, which, like silvopasture, entails an open stand of trees dispersed across the production area, unlike conservation buffer, which occupy ~5% of the production area and mainly intercept N leaving the field or pasture).

CPS 336 Soil Carbon Amendment

"Can promote C sequestration (soil and biomass) by enhancing plant growth especially in semiarid regions. Use of organic soil amendments and fertilizers in lieu of soluble NPK alone can improve SOC stocks by 30%. Reduces GHG emissions when feedstocks are diverted from alternative waste streams. Compost improves microbial N cycling and may reduce emissions compared to poultry litter. Biochar mitigates N_2O emissions by 25-40%. May increase N_2O emissions if low C:N material is tilled in."

References:

DeLonge et al, 2013; Reeve et al., 2012, 2023; Ryals & Silver, 2013 (compost applications can build SOC beyond the C in the compost itself by enhancing plant growth, root biomass, and rhizodeposition, especially in semiarid regions).

Beillouin et al., 2023 (Organic soil amendments on cropland SOC +29% based on ~500 comparisons; on grassland +34% based on ~200 comparisons; substituting organic nutrient sources for some or all of the soluble fertilizer on cropland +34% based on ~200 comparisons).

Shi et al., 2024. (Organic fertilizers improved SOC in grassland by 14% in cool climates < 15°C annual mean and 64% in warm climates >15°C; in cropland by 32% in cool climates and 34% in warm climates. Soluble fertilizers on grassland improved SOC by only 2%).

Pattey et al, 2005; DeLonge et al., 2013 (composting emits less GHG than alternative fates such as landfill or manure lagoon).

Bhowmik et al, 2016 (Compost with C:N ratio ~20 improved microbial N cycling and reduced surplus soluble N compared to poultry litter applied at equivalent N rates in an 11-year organic vegetable farming systems trial).

Grados et al., 2022; Young et al., 2022 (meta-analyses showing biochar mitigating soil N_2O emissions by 27% and 40%, respectively).

CPS 585 Stripcropping

"May sequester or retain more SOC than the same crop rotation but without alternating strips (e.g. entire field in corn, soy, wheat, and clover in years 1, 2, 3, and 4) Enhances the efficacy of the crop rotation in reducing soil erosion in sloping or wind-exposed fields. Soil erosion is a substantial factor in SOC losses from the eroding field and degradation of SOC in water- or windborne soil may be accelerated. May mitigate N_2O depending on crop species composition of the strips."

References:

Biardeau et al., 2016 (COMET Farm estimates 140 lb/ac-yr vs 120 lb/ac-yr for conservation crop rotation).

Lal., 2020; Zheng et al., 2025. (Erosion selectively removes the SOC-rich fractions of the soil, so that loss of 5 tons/ac-yr – the "T" value for many soils – might remove 200-300 lb SOC/ac-yr. Rates of SOC oxidation may be accelerated during transport of wind- or water-eroded soil, and the capacity of eroding fields to support new carbon sequestration through photosynthesis may be diminished. Soil erosion is the primary target resource concern addressed through CPS 585 Stripcropping).

Baas et al., 2015; Davis et al., 2019; Eagle et al., 2017; Han et al., 2017; Li et al., 2009 (Heavily N-fertilized crops like corn or head brassicas account for the vast majority of soil N_2O emissions over the course of a rotation. N_2O emissions increase exponentially as soil soluble N levels increase beyond the crop's capacity to utilize the N. Alternating strips of heavily fertilized and unfertilized crops may reduce the amount of surplus soluble N in the soil and thereby reduce emissions, especially if deep-rooted perennial forage or cover crops that scavenge N are included in the rotation).

CPS 612 Tree/Shrub Establishment

"Likely to sequester 800-1500 lb C (soil and biomass) per acre annually depending on species planted and soil/climate conditions. May reduce N_2O by 0.5-1.0 lb N_2O-N/ac-yr by reducing N input needs and intercepting excess soluble N."

References:

Biardeau et al., 2016 gives 1,380 lb/ac-yr for this practice; however, circumstances under which the practices are implemented may vary, so this represents the full range of COMET Farm estimates for agroforestry practices.

See other Agroforestry practices for more references.

CPS 380 Windbreak / Shelterbelt Establishment and Renovation

"Sequesters 1,280-1,430 lb C/ac-yr in soil and woody biomass within the area of the windbreak (typically 5% of the cropland area in which practice is implemented). May mitigate N_2O emissions especially within and near the windbreak planting."

References

Biardeau et al., 2016 (1,260 lb/ac-yr COMET Farm estimate).

Possu et al, 2016 (based on growth records of more than 275,000 trees from 30,000 sites across the US, aboveground biomass C accrual within a 10-ft wide windbreak row averaged 2,190 lb/ac-yr for conifers and 3,920 lb/ac-yr for broadleaf trees, ranging from a low of ~900 lb/ac-yr in New England to a maximum of 12,000 lb/ac-yr for eastern cottonwood in the southern plains. Windbreaks occupy about 3-5% of field area).

For N_2O mitigation, Thevathesan and Gordon, 2004 estimate of 0.6 lb N_2O-N/ac-yr mitigation for alley crops – may apply only in areas near the windbreak.

ABOUT THE NATIONAL SUSTAINABLE AGRICULTURE COALITION

The National Sustainable Agriculture Coalition (NSAC) advances federal farm and food policies that build sustainable, resilient, and equitable ecosystems and communities.

NSAC is an alliance of more than 170 grassroots organizations founded to:

- Equip, engage, and empower the grassroots of sustainable agriculture and food systems for the health and vitality of the movement; and

- Research, develop, and advocate for federal farm and food policy that promotes sustainability and equity across the policy life cycle from inception to implementation.

We envision a future where farmers, workers, and communities sustain a thriving food and farm system that nourishes people, stewards our environment, and builds strong economies.

See **https://sustainableagriculture.net/about-us/members** for a full list of NSAC members.

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