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# COMET-Planner

Carbon and greenhouse gas evaluation for NRCS conservation practice planning

*A companion report to*

www.comet-planner.com

# COMET-Planner

## Carbon and Greenhouse Gas Evaluation for NRCS Conservation Practice Planning

A companion report to www.comet-planner.com

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## Introduction

The following report serves as a companion to www.comet-planner.com, an evaluation tool designed to provide approximate greenhouse gas mitigation potentials for NRCS conservation practices. This report provides the rationale, approach, and documentation of methods for COMET-Planner.

## Purpose and Rationale

Conservation planners must assess a range of environmental, agronomic and economic impacts of implementing conservation practices on farms. While environmental impacts such as soil erosion control, improved soil quality, reduced nonpoint source pollution and a number of other site-specific benefits are currently considered, conservation practices may also have significant climate benefits, through carbon sequestration and/or reduction of greenhouse gas (GHG) emissions. If conservation planners wish to incorporate greenhouse gas impacts in their planning process, they will need access to quick, easy-to-use tools to assess greenhouse gas impacts of conservation practices on farms. NRCS has developed a qualitative ranking of conservation practices for carbon sequestration and GHG emission reduction (Appendix II). The qualitative ranking table provided the starting point for COMET-Planner, which was expanded to provide more quantitative information, in a web-based platform.

Carbon sequestration and greenhouse gas emission reduction values provided in this report and generated in www.comet-planner.com are intended to provide generalized estimates of the greenhouse gas impacts of conservation practices for initial planning purposes. Site-specific conditions are required for more detailed assessments of greenhouse gas dynamics on farms. Those interested in conducting more detailed analyses of on-farm greenhouse gas emissions are encouraged to visit www.comet-farm.com.

## Approach

Recent meta-analyses and literature reviews have estimated the impacts of land use changes, agricultural management practices and mitigation strategies on carbon sequestration and greenhouse gas emission reductions. Reported land use and management activities were compared to, and aligned with, NRCS Conservation Practice Standards to estimate the greenhouse gas impacts of implementing NRCS conservation practices on farms. Emission reduction coefficients derived from meta-analyses and literature reviews were generalized at the national-scale and differentiated by broad climate zones, if data was available. The U.S. was divided into broad climate categories using the Intergovernmental Panel on Climate Change (IPCC) climate classifications (IPCC 2006) (Figure 1). Ranges for GHG emission reduction coefficients generally represent minimum and maximum values reported in meta-analyses and literature reviews. When empirically-based ranges were not available, proximate ranges were calculated as +/- 100% of the average emission coefficient. All estimates are presented as emission reductions relative to baseline management, thus positive values denote a decrease in GHG emissions and negative values denote an increase in GHG emissions due to the implementation of a conservation practice. It should be noted that soil and biomass carbon stock increases in response to these conservation practices are limited in duration – eventually these stocks approach a new equilibrium condition and thus carbon dioxide removals do not continue indefinitely. The carbon dioxide reductions reported should be viewed as average values over a 20 year duration.

## *Units*

Approximate carbon sequestration and greenhouse gas emission reduction estimates are given in ***Mg $CO_2$ eq per acre per year***, where:

**Mg = Megagrams (same as Metric Tonnes)**
*Megagrams or Metric Tonnes are similar to English (or 'short') tons; 1 Megagram (Metric Ton) = 1.1 English (short) tons*

**$CO_2$ eq = Carbon Dioxide Equivalents**
*Carbon dioxide equivalent is a measure used to compare the emissions from various greenhouse gases, based upon their global warming potential. Carbon dioxide equivalents are used in COMET-Planner to allow users to compare emissions of carbon dioxide, nitrous oxide and methane in standardized units.*

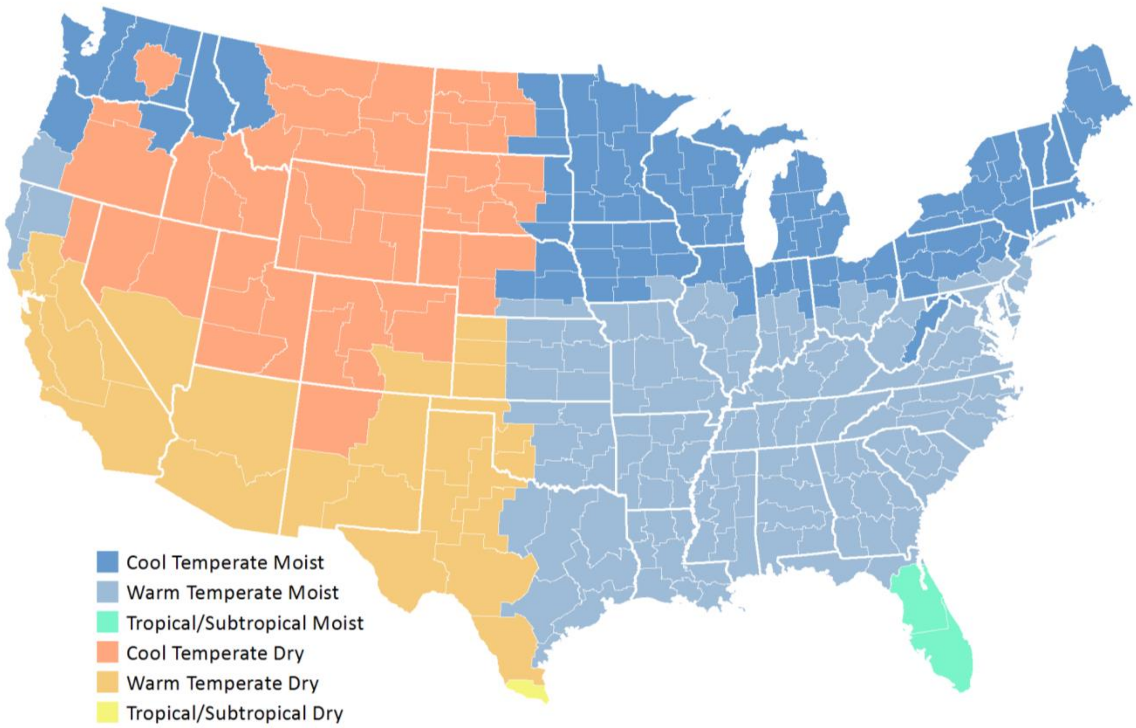


Figure 1. Broad climate categories for the U.S (IPCC 2006).

## Organization

NRCS conservation practices are grouped into five broad categories: cropland management, conversion of annual cropland to perennial herbaceous cover, conversion of annual cropland to woody cover, grazing land management, and restoration of disturbed lands. Following each overview of the broad categories, are informational sheets for each practice that provide a description of the practice, how the practice was analyzed for COMET-Planner, and approximate carbon sequestration and greenhouse gas emission reduction estimates. All emission reduction coefficients, ranges, a short explanation of estimation methods, and primary sources are presented in Appendix I.

# Cropland Management

## Conservation Benefits

NRCS conservation practices for cropland management have multiple objectives that may include reducing soil erosion, maintaining or increasing soil quality and organic matter content, improving air quality, minimizing nonpoint source pollution from agricultural nutrients and chemicals, enhancing soil moisture efficiency and a number of other agronomic and environmental benefits. Cropland management practices are generally applied to annual cropping systems, although benefits may be similar for perennial cropland systems or other lands where these practices may be applied. While NRCS promotes these cropland management practices for conservation benefits, there may be additional greenhouse gas benefits of implementing these practices on farms.

**NRCS Conservation Practices**

Conventional Tillage to No-Till (CPS 329)
Conventional Tillage to Reduced Till (CPS 345)
Nutrient Management - Improved Nitrogen Fertilizer Management (CPS 590)
Nutrient Management – Replacing Synthetic Nitrogen Fertilizer with Soil Amendments (CPS 590)
Conservation Crop Rotation (CPS 328)
Cover Crops (CPS 340)
Stripcropping (CPS 585)

## Greenhouse Gas Emissions

The main sources of greenhouse gas emissions in cropland agriculture are carbon dioxide from soils and nitrous oxide from use of nitrogen fertilizers (CAST 2011). Practices that cause soil disturbance, such as tillage, may increase emissions of carbon dioxide from soil, whereas practices that reduce soil disturbance or increase organic matter carbon inputs may sequester carbon in the soil (Ogle et al. 2005). Adoption of **no-till** or **reduced tillage** has been shown in previous research to enhance soil carbon storage in soils, as compared to conventional (full-width) tillage (Denef et al. 2011). Organic matter carbon inputs may be increased through higher plant residue inputs from more productive annual crops, intensified cropping frequency or inclusion of perennial crops in rotation. As such, practices such as **conservation crop rotations** that include perennial crops or higher cropping frequency, use of seasonal **cover crops**, or **stripcropping** with perennial crops may enhance soil carbon sequestration. Organic matter inputs may also be increased through addition of organic matter amendments, such as **mulching** with straw or crop residues (high C:N ratios), or amendments that may fully or partially replace nitrogen fertilizer, such as manure or other organic by-products. Agricultural soil nitrous oxide emissions account for approximately 4.5 percent of total U.S. greenhouse gas emissions (EPA 2014); however there are a number of strategies that farmers may use to reduce nitrous oxide emissions. The most dominant source of nitrous oxide emissions from management of soils is from the use of nitrogen fertilizers (EPA 2014). **Improved nitrogen fertilizer management** strategies may include reducing the rate of nitrogen fertilizer applied, using nitrification inhibitors, or shifting timing of applications from the fall to the spring (ICF International 2013). Nitrogen rate reductions, especially when additions exceed plant demand, have significant potential to reduce nitrous oxide emissions. Nitrification inhibitors inhibit microbial activity that produce emissions and may enhance availability of nitrogen to plants (Akiyama et al. 2010). When nutrients are applied in the fall, significant amounts of nitrogen may be lost from the soil as nitrous oxide before spring planting of crops. Shifting the timing of nitrogen applications from the fall to the spring may reduce nitrous oxide emissions from fertilizer (ICF International 2013). In addition to soil processes, carbon dioxide emissions from fossil fuel use can be a major source of on-farm greenhouse gas emissions (CAST 2011). **Improved fuel-efficiency of farm equipment** will reduce carbon dioxide emissions from management activities.

## Conventional Tillage to No-Till
## (Conservation Practice Standard 329)

### NRCS Practice Information

DEFINITION: Limiting soil disturbance to manage the amount, orientation and distribution of crop and plant residue on the soil surface year around.

PURPOSE:
- Reduce sheet, rill and wind erosion
- Reduce tillage-induced particulate emissions
- Maintain or increase soil quality and organic matter content
- Reduce energy use
- Increase plant-available moisture
- Provide food and escape cover for wildlife

CONDITIONS WHERE PRACTICE APPLIES: This practice applies to all cropland. This practice only involves an in-row soil tillage operation during the planting operation and a seed row/furrow closing device. There is no full-width tillage performed from the time of harvest or termination of one cash crop to the time of harvest or termination of the next cash crop in the rotation regardless of the depth of the tillage operation.


Photo by USDA NRCS

### COMET-Planner Practice Information

COMET-Planner estimates assume a conversion from conventional (full-width) tillage to no-till, as defined by the NRCS practice standard. Impacts on greenhouse gases include soil carbon change from decreased soil disturbance and nitrous oxide emissions from changes in the soil environment (does not include changes in nitrogen fertilizer that may accompany tillage changes).

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Conventional Tillage to No-Till (CPS 329)** | Dry/semiarid | 0.22 (0.02 – 0.54) | 0.13 (0.06 – 0.20) | Not estimated |
| | Moist/humid | 0.42 (0.13 – 0.77) | -0.11 (-0.16 – -0.08) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Carbon estimates represent averages of soil carbon change reported in recent reviews (Eagle et al. 2012, ICF International 2013, Ogle et al. 2010). The highest values for soil carbon were in corn systems with means of 0.42 and 0.60 Mg $CO_2$ eq acre$^{-1}$ y$^{-1}$ in dry and humid climates respectively. Estimates for nitrous oxide emissions represent the effects of changing tillage only and assume N fertilizer rates do not change (Swan et al. unpubl.). *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

## Conventional Tillage to Reduced Till
## (Conservation Practice Standard 345)

**NRCS Practice Information**

DEFINITION: Managing 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.

PURPOSE:

- Reduce sheet, rill and wind erosion
- Reduce tillage-induced particulate emissions
- Maintain or increase soil quality and organic matter content
- Reduce energy use
- Increase plant-available moisture

CONDITIONS WHERE PRACTICE APPLIES: This practice applies to all cropland. This practice includes tillage methods commonly referred to as mulch tillage or conservation tillage where the entire soil surface is disturbed by tillage operations such as chisel plowing, field cultivating, tandem disking, or vertical tillage. It also includes tillage/planting systems with few tillage operations (e.g. ridge till) but which do not meet the Soil Tillage Intensity Rating (STIR) criteria for Residue and Tillage Management - No Till (code 329)


**COMET-Planner Practice Information**

COMET-Planner estimates assume a conversion from conventional (full-width) tillage to any type of reduced tillage (excluding no-till), as defined by the NRCS practice standard. Impacts on greenhouse gases include soil carbon change from decreased soil disturbance and nitrous oxide emissions from changes in the soil environment (does not include changes in nitrogen fertilizer that may accompany tillage changes).

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Conventional Tillage to Reduced Till (CPS 345)** | Dry/semiarid | 0.10 (0.04 – 0.19) | 0.07 (0 – 0.15) | Not estimated |
| | Moist/humid | 0.13 (0.02 – 0.22) | 0.07 (0 – 0.15) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Carbon estimates represent averages of soil carbon change reported in recent reviews (Eagle et al. 2012, ICF International 2013, Ogle et al. 2010). The highest values for soil carbon were in corn systems with means of 0.16 and 0.14 $Mg\ CO_2$ eq $acre^{-1}\ y^{-1}$ in dry and humid climates respectively. Nitrous oxide emission changes were from Eagle et al. (2012). Nitrous oxide ranges are +/- 100% of reported value. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

## Nutrient Management – Improved Nitrogen Fertilizer Management (Conservation Practice Standard 590)

### NRCS Practice Information

DEFINITION: Managing the amount (rate), source, placement (method of application), and timing of plant nutrients and soil amendments.

PURPOSE:

- To budget, supply, and conserve nutrients for plant production
- To minimize agricultural nonpoint source pollution of surface and groundwater resources
- To properly utilize manure or organic by-products as a plant nutrient source
- To protect air quality by reducing odors, nitrogen emissions (ammonia, oxides of nitrogen), and the formation of atmospheric particulates
- To maintain or improve the physical, chemical, and biological condition of soil

CONDITIONS WHERE PRACTICE APPLIES: This practice applies to all lands where plant nutrients and soil amendments are applied. This standard does not apply to one-time nutrient applications to establish perennial crops.


Photo by USDA NRCS

### COMET-Planner Practice Information

COMET-Planner estimates assume adoption of multiple strategies for improved nitrogen management, including reducing nitrogen fertilizer rates by 15 percent, use of nitrification inhibitors (source) and a shift from fall to spring nitrogen applications (timing). The greenhouse gas impacts of these practices are estimated for nitrous oxide emissions. Emission changes result from reduced use of nitrogen fertilizers, and soil processes that may be affected by the use of nitrification inhibitors and a shift in application timing.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Nutrient Management – Improved Nitrogen Fertilizer Management (CPS 590)** | Dry/semiarid | Not estimated | 0.04 (0 – 0.05) | Not estimated |
| | Moist/humid | Not estimated | 0.11 (0 – 0.14) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Average fertilizer rates by major crop types (USDA-ERS 2014) represented baseline emissions, to which a 15% rate reduction was applied. Average nitrogen rates were area-weighted by crop types within climate zones. Nitrous oxide emission rates were based on Ogle et al. (2010) emission factors, and emissions reduction from nitrification inhibitors were based on an average of emission reductions from Ogle et al. (2010) and Akiyama et al. (2010). Emissions reductions from a switch from fall to spring N application were from ICF International (2013) and area-weighted by major crop types (USDA-NASS 2012) within climate zones. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

## Nutrient Management – Replacing Synthetic Nitrogen Fertilizer with Soil Amendments (Conservation Practice Standard 590)

**NRCS Practice Information**

DEFINITION: Managing the amount (rate), source, placement (method of application), and timing of plant nutrients and soil amendments.

PURPOSE:
- To budget, supply, and conserve nutrients for plant production
- To minimize agricultural nonpoint source pollution of surface and groundwater resources
- To properly utilize manure or organic by-products as a plant nutrient source
- To protect air quality by reducing odors, nitrogen emissions (ammonia, oxides of nitrogen), and the formation of atmospheric particulates
- To maintain or improve the physical, chemical, and biological condition of soil

CONDITIONS WHERE PRACTICE APPLIES: This practice applies to all lands where plant nutrients and soil amendments are applied. This standard does not apply to one-time nutrient applications to establish perennial crops.


**COMET-Planner Practice Information**

COMET-Planner estimates assume a full or partial replacement of synthetic nitrogen fertilizer with soil organic matter amendments, such as manure or other organic by-products. It is assumed that total nitrogen addition rates will not change and therefore nitrous oxide emissions will not be significantly different with soil amendments. Emission reductions are associated with soil carbon sequestration from increased inputs of carbon from manure or organic by-products.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Nutrient Management – Replacing Synthetic Nitrogen Fertilizer with Soil Amendments (CPS 590)** | Dry/semiarid | 1.00 (0.40 – 2.17) | Not estimated | Not estimated |
| | Moist/humid | 1.75 (0.85 – 2.51) | Not estimated | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Emissions reductions for soil carbon were estimated using the Intergovernmental Panel on Climate Change (IPCC) inventory method for annual cropland, using the emission factors for high input with amendment (dry = 1.34, humid = 1.38) from Eve et al. (2014). Reference soil carbon stocks were from Eve et al. (2014) and estimated stock changes were area-weighted using total IPCC soil areas classified from SSURGO soils data, by IPCC climate regions (IPCC 2006, Soil Survey Staff 2011). *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

## Conservation Crop Rotation
## (Conservation Practice Standard 328)


### NRCS Practice Information

DEFINITION: A planned sequence of crops grown on the same ground over a period of time (i.e. the rotation cycle).

PURPOSE:

- Reduce sheet, rill and wind erosion
- Maintain or increase soil health and organic matter content
- Reduce water quality degradation due to excess nutrients
- Improve soil moisture efficiency
- Reduce the concentration of salts and other chemicals from saline seeps
- Reduce plant pest pressures
- Provide feed and forage for domestic livestock
- Provide food and cover habitat for wildlife, including pollinator forage, and nesting

CONDITIONS WHERE PRACTICE APPLIES: This practice applies to all cropland where at least one annually-planted crop is included in the crop rotation.

### COMET-Planner Practice Information

COMET-Planner estimates for instituting conservation crop rotations are based on the scenarios of decreasing fallow frequencies and/or adding perennial crops to rotations. Greenhouse gas impacts are largely for increases in soil carbon stocks due to increased carbon inputs from intensified crop rotations or perennial crops in rotation. Decreased soil disturbance under perennial crops may also increase soil carbon stocks.

| Emission Reduction Coefficients* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Conservation Crop Rotation (CPS 328)** | Dry/semiarid | 0.26 (-0.18 – 0.71) | 0 (-0.02 – 0.02) | Not estimated |
| | Moist/humid | 0.21 (0 – 0.49) | 0.01 (0 – 0.02) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Values for dry climates were averaged from soil carbon sequestration rates from eliminating summer fallow (Eagle et al. 2012, Sherrod et al. 2003) and adding perennial crops to rotations (Eagle et al. 2012). Nitrous oxide emissions from these scenarios average to essentially zero, since increased cropping intensity may lead to an increase in nitrogen application, whereas perennial crops in rotation likely result in a decrease in nitrogen fertilization. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

# Cover Crops
## (Conservation Practice Standard 340)

**NRCS Practice Information**

DEFINITION: Grasses, legumes, and forbs planted for seasonal vegetative cover.

PURPOSE:
- Reduce erosion from wind and water
- Maintain or increase soil health and organic matter content
- Reduce water quality degradation by utilizing excessive soil nutrients
- Suppress excessive weed pressures and break pest cycles
- Improve soil moisture use efficiency
- Minimize soil compaction

CONDITIONS WHERE PRACTICE APPLIES: All lands requiring seasonal vegetative cover for natural resource protection or improvement.


Photo by USDA NRCS

**COMET-Planner Practice Information**

COMET-Planner estimates for the addition of seasonal cover crops to annual cropland represent the impacts of increased carbon inputs from crop residues on soil carbon stocks.

| **Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions*** | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Cover Crops (CPS 340)** | Dry/semiarid | 0.21 (0.08 – 0.45) | 0.05 (0.0 – 0.10) | Not estimated |
| | Moist/humid | 0.32 (0.16 – 0.46) | 0.05 (0.0 – 0.10) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Limited data was available on the influence of cover crops in recent reviews. Emissions reductions for soil carbon were estimated using the Intergovernmental Panel on Climate Change (IPCC) inventory method for annual cropland, using the emission factors for high input without amendment (dry = 1.07, humid = 1.07) from Eve et al. (2014). Reference soil carbon stocks were from Eve et al. (2014) and estimated stock changes were area-weighted using total IPCC soil areas classified from SSURGO soils data, by IPCC climate regions (IPCC 2006, Soil Survey Staff 2011). Nitrous oxide emissions changes were from Eagle et al. (2012). *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

# Stripcropping
## (Conservation Practice Standard 585)

**NRCS Practice Information**
DEFINITION: Growing planned rotations of row crops, forages, small grains, or fallow in a systematic arrangement of equal width strips across a field.

PURPOSE:
- Reduce soil erosion from water and transport of sediment and other water-borne contaminants
- Reduce soil erosion from wind
- Protect growing crops from damage by wind-borne soil particles

CONDITIONS WHERE PRACTICE APPLIES: This practice applies on cropland or other land where crops are grown.


**COMET-Planner Practice Information**
COMET-Planner estimates for stripcropping represent the addition of dense grasses or legumes, hay crops or other perennial cover, grown in strips with annual crops. Strips of perennial cover are estimated to increase soil carbon stocks through increased carbon inputs from plant residues and reduced soil disturbance. Nitrous oxide emission reductions are based the assumption that perennial strips are not fertilized.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Stripcropping (CPS 585)** | Dry/semiarid | 0.11 (0.0 – 0.24) | 0.05 (0.02 – 0.22) | Not estimated |
| | Moist/humid | 0.11 (0.0 – 0.24) | 0.13 (0.06 – 0.58) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Stripcropping is assumed to include dense grasses or legumes, hay crops or other perennial cover in strips. Therefore mitigation was estimated as half the rate of soil carbon sequestration for perennials in rotation (Eagle et al. 2012). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014), emissions factors for the U.S. (Ogle et al. 2010), and the assumption that rates are reduced by 50% on perennial strips. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

# Mulching
## (Conservation Practice Standard 484)

### NRCS Practice Information

DEFINITION: Growing planned rotations of row crops, forages, small grains, or fallow in a systematic arrangement of equal width strips across a field.

PURPOSE:
- Reduce soil erosion from water and transport of sediment and other water-borne contaminants
- Reduce soil erosion from wind
- Protect growing crops from damage by wind-borne soil particles

CONDITIONS WHERE PRACTICE APPLIES: This practice applies on cropland or other land where crops are grown.


### COMET-Planner Practice Information

COMET-Planner estimates for mulching represent the addition of high carbon (low nitrogen) organic matter amendments, such as straw or crop residues, to croplands. The addition of organic matter carbon in mulch may increase soil carbon stocks in annual croplands.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Mulching (CPS 484)** | Dry/semiarid | 0.21 (0.08 – 0.45) | Not estimated | Not estimated |
| | Moist/humid | 0.32 (0.16 – 0.46) | Not estimated | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Limited data was available on the influence of mulching in recent reviews. Emissions reductions for soil carbon were estimated using the Intergovernmental Panel on Climate Change (IPCC) inventory method for annual cropland, using the emission factors for high input without amendment (dry = 1.07, humid = 1.07) from Eve et al. (2014). Reference soil carbon stocks were from Eve et al. (2014) and estimated stock changes were area-weighted using total IPCC soil areas classified from SSURGO soils data, by IPCC climate regions (IPCC 2006, Soil Survey Staff 2011). *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

## Combustion System Improvement (Improved Fuel Efficiency of Farm Equipment) (Conservation Practice Standard 372)

**NRCS Practice Information**

DEFINITION: Installing, replacing, or retrofitting agricultural combustion systems and/or related components or devices for air quality and energy efficiency improvement.

PURPOSE:

- To improve air quality by addressing the air quality resource concerns for particulate matter and ozone precursors by mitigating actual or potential emissions of oxides of nitrogen and/or fine particulate matter
- To improve the energy efficiency of agricultural combustion systems

CONDITIONS WHERE PRACTICE APPLIES: This practice applies to any agricultural operation that operates an agricultural combustion system, including stationary, portable, mobile, and self-propelled equipment. The combustion system must be used primarily for agricultural and/or forestry activities.


Photo by USDA NRCS

**COMET-Planner Practice Information**

COMET-Planner estimates focus only on improved fuel efficiency of farm equipment commonly used in cropland management. Carbon dioxide emission reductions were estimated from a 15 percent improvement in fuel efficiency of farm equipment.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Combustion System Improvement (Improved Fuel Efficiency of Farm Equipment)** | Dry/semiarid | 0.01 (0.00 – 0.02) | Not estimated | Not estimated |
| | Moist/humid | 0.01 (0.00 – 0.02) | Not estimated | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Total emissions from common tillage operations, as reported in West and Marland (2002), were area-weighted by total area of tillage systems in the U.S. (CTIC 2008). Emissions estimates were then reduced by 15% to represent a 15% improvement in fuel efficiency. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

# Cropland to Herbaceous Cover

## Conservation Benefits

NRCS conservation practices for conversion of annual cropland to perennial herbaceous cover have multiple objectives that may include reducing soil erosion, improving water and air quality, enhancing wildlife habitat, protecting crops from wind damage, stabilizing steep slopes, and/or reducing sediment and contaminant loadings in runoff. Converting all or part of cropland fields to perennial herbaceous cover may also have significant greenhouse gas benefits.

**NRCS CONSERVATION PRACTICES**

- CONSERVATION COVER (CPS 327)
- FORAGE AND BIOMASS PLANTING (CPS 512)
- HERBACEOUS WIND BARRIERS (CPS 603)
- VEGETATIVE BARRIERS (CPS 601)
- RIPARIAN HERBACEOUS COVER (CPS 390)
- CONTOUR BUFFER STRIPS (CPS 332)
- FIELD BORDER (CPS 386)
- FILTER STRIP (CPS 393)
- GRASSED WATERWAY (CPS 412)

## Greenhouse Gas Emissions

While the main sources of emissions from cropland agriculture are carbon dioxide emissions from soils and nitrous oxide emissions from nitrogen fertilizers (CAST 2011), conversion to perennial herbaceous cover has significant potential to reduce emissions and sequester atmospheric carbon. Lands that have been previously retired from cropland agriculture and converted to perennial cover, such as those under the Conservation Reserve Program (CRP), are predicted to be significant agricultural soil carbon sinks in the U.S. (EPA 2014). Cropland soils are often subject to soil disturbance from tillage and cessation of tillage under permanent cover may reduce carbon dioxide emissions from soils. Perennial vegetation also contributes increased carbon inputs from plant residues, further enhancing soil carbon sequestration potential (Denef et al. 2011). Nitrogen fertilizer can be a major source of nitrous oxide emissions from cropland soils as described under Cropland Management; however fertilizer is not generally applied to herbaceous cover, thus reducing emissions.

# Conservation Cover
## (Conservation Practice Standard 327)

**NRCS Practice Information**

DEFINITION: Establishing and maintaining permanent vegetative cover

PURPOSE:

- Reduce soil erosion and sedimentation
- Improve water quality
- Improve air quality
- Enhance wildlife habitat and pollinator habitat.
- Improve soil quality
- Manage plant pests

CONDITION WHERE PRACTICE APPLIES: This practice applies on all lands needing permanent vegetative cover. This practice does not apply to plantings for forage production or to critical area plantings.


**COMET-Planner Practice Information**

COMET-Planner estimates for conservation cover planting are constructed from the scenario of converting conventionally managed cropland to permanent unfertilized herbaceous cover. Impacts on greenhouse gases include changes in soil organic matter carbon due to cessation of tillage and increases in carbon inputs from plant residues, and decreased nitrous oxide emissions from synthetic fertilizer.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Conservation Cover (CP 327)** | Dry/semiarid | 1.05 (0.68 – 1.40) | 0.08 (0 – 0.15) | Not estimated |
| | Moist/humid | 0.98 (0.64 – 1.34) | 0.28 (0 – 0.50) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Soil carbon estimates are based on studies of cropland converted to grassland in the U.S. (Ogle et al. 2010). Nitrous oxide estimates are based on weighted average fertilizer rates for major crops (USDA-ERS 2014) and emissions factors for the U.S. (Ogle et al. 2014) and the assumption that herbaceous cover is unfertilized. Range for nitrous oxide is based on range of average fertilizer rates reported. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated*.

## Forage and Biomass Planting
## (Conservation Practice Standard 512)

**NRCS Practice Information**

DEFINITION: Establishing adapted and/or compatible species, varieties, or cultivars of herbaceous species suitable for pasture, hay, or biomass production.

PURPOSE:
- Improve or maintain livestock nutrition and/or health.
- Provide or increase forage supply during periods of low forage production
- Reduce soil erosion
- Improve soil and water quality
- Produce feedstock for biofuel or energy production

CONDITIONS WHERE PRACTICE APPLIES: This practice applies all lands suitable to the establishment of annual, biennial or perennial species for forage or biomass production.


Photo by USDA NRCS

**COMET-Planner Practice Information**

COMET-Planner estimates for forage and biomass planting are constructed from two scenarios: 1) full conversion -replacing all crops in a conventionally managed continuous grain rotation with continuous unfertilized forage/biomass crops; 2) partial conversion - replacing a conventionally managed continuous grain rotation with a grain – forage/biomass rotation in which the forage/biomass crop is unfertilized.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2$ eq $ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2$ eq $ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2$ eq $ac^{-1}\ y^{-1}$) Average (Range)** |
| **Forage and Biomass Planting – Full Conversion (CP 512)** | Dry/semiarid | 0.27 (-0.35 – 0.81) | 0.10 (0 – 0.19) | Not estimated |
| | Moist/humid | 0.27 (-0.35 – 0.81) | 0.10 (0 – 0.19) | Not estimated |
| **Forage and Biomass Planting – Partial Conversion (CP 512)** | Dry/semiarid | 0.21 (0 – 0.49) | 0.01 (0 – 0.02) | Not estimated |
| | Moist/humid | 0.21 (0 – 0.49) | 0.01 (0 – 0.02) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Soil carbon estimates were based on a review of studies of cropland conversion to forage in the U.S. (Eagle et al. 2012). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014), emissions factors for the U.S. (Ogle et al. 2010), and the assumption that herbaceous cover is unfertilized. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

# Herbaceous Wind Barriers
## (Conservation Practice Standard 603)

NRCS Practice Information

DEFINITION: Herbaceous vegetation established in rows or narrow strips in the field across the prevailing wind direction.

PURPOSE:

- Reduce soil erosion from wind
- Reduce soil particulate emissions to the air
- Protect growing crops from damage by wind or wind-borne soil particles
- Enhance snow deposition to increase plant-available moisture

CONDITIONS WHERE PRACTICE APPLIES: This practice applies to lands where crops or forages are grown.


Photo by USDA NRCS

COMET-Planner Practice Information

COMET-Planner estimates for conservation cover planting are constructed from the scenario of converting strips of conventionally managed cropland to permanent unfertilized herbaceous cover. Impacts on greenhouse gases include changes in soil organic matter carbon due to cessation of tillage and increased carbon inputs from plant residues, and decreased nitrous oxide emissions from synthetic fertilizer.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide (Mg $CO_2$ eq $ac^{-1}$ $y^{-1}$) Average (Range)** | **Nitrous Oxide (Mg $CO_2$ eq $ac^{-1}$ $y^{-1}$) Average (Range)** | **Methane (Mg $CO_2$ eq $ac^{-1}$ $y^{-1}$) Average (Range)** |
| **Herbaceous Wind Barriers (CP 603)** | Dry/semiarid | 1.05 (0.68 – 1.40) | 0.08 (0 – 0.15) | Not estimated |
| | Moist/humid | 0.98 (0.64 – 1.34) | 0.28 (0 – 0.50) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Soil carbon estimates were based on studies of cropland converted to grassland in the U.S. (Ogle et al. 2010). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014), emissions factors for the U.S. (Ogle et al. 2010), and the assumption that herbaceous cover is unfertilized. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

# Vegetative Barriers
## (Conservation Practice Standard 601)

### NRCS Practice Information

DEFINITION: Permanent strips of stiff, dense vegetation established along the general contour of slopes or across concentrated flow areas.

PURPOSE:
- Reduce sheet and rill erosion
- Reduce ephemeral gully erosion
- Manage water flow
- Stabilize steep slopes
- Trap sediment

CONDITIONS WHERE PRACTICE APPLIES: This practice applies to all land uses where sheet and rill and/or concentrated flow erosion are resource concerns. This practice is not well-suited to soils that are shallow to rock or other restrictive layers and where tillage is used on the cropped strips. The “benching” process that occurs on slopes where barriers are installed can expose soil material unfavorable for crop growth.


Photo by USDA NRCS

### COMET-Planner Practice Information

COMET-Planner estimates for vegetative barrier plantings are constructed from the scenario of converting strips of conventionally managed cropland to permanent, unfertilized, herbaceous cover. Impacts on greenhouse gases include changes in soil organic matter carbon due to cessation of tillage and increased carbon inputs from plant residues, and decreased nitrous oxide emissions from synthetic fertilizer.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2$ eq $ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2$ eq $ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2$ eq $ac^{-1}\ y^{-1}$) Average (Range)** |
| **Vegetative Barriers (CP 601)** | Dry/semiarid | 1.05 (0.68 – 1.40) | 0.08 (0 – 0.15) | Not estimated |
| | Moist/humid | 0.98 (0.64 – 1.34) | 0.28 (0 – 0.50) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Soil carbon estimates were based on studies of cropland converted to grassland in the U.S. (ogle et al. 2010). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014), emissions factors for the U.S. (Ogle et al. 2010), and the assumption that herbaceous cover is unfertilized. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated*.

## Riparian Herbaceous Cover
### (Conservation Practice Standard 390)

**NRCS Practice Information**

DEFINITION: Herbaceous plants tolerant of intermittent flooding or saturated soils established or managed as the dominant vegetation in the transitional zone habitats.

PURPOSE:

- Provide or improve food and cover for fish, wildlife and livestock
- Improve and maintain water quality
- Reduce erosion and improve stability to stream banks and shorelines
- Increase net carbon storage in the biomass and soil
- Restore, improve or maintain the desired plant communities
- Enhance stream bank protection as part of stream bank soil bioengineering practices.

CONDITIONS WHERE PRACTICE APPLIES:

- Areas adjacent to perennial and intermittent watercourses or water bodies where the natural plant community is dominated by herbaceous vegetation that is tolerant of periodic flooding or saturated soils
- Where channel and stream bank stability is adequate to support this practice
- Where the riparian area has been altered and the potential natural plant community has changed


**COMET-Planner Practice Information**

COMET-Planner estimates for riparian herbaceous cover plantings are constructed from the scenario of converting conventionally managed cropland to permanent unfertilized herbaceous cover. Impacts on greenhouse gases include changes in soil organic matter carbon due to cessation of tillage and increased carbon inputs from plant residues, and decreased nitrous oxide emissions from synthetic fertilizer.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Riparian Herbaceous Cover (CP 390)** | Dry/semiarid | 1.05 (0.68 – 1.40) | 0.08 (0 – 0.15) | Not estimated |
| | Moist/humid | 0.98 (0.64 – 1.34) | 0.28 (0 – 0.50) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Soil carbon estimates were based on studies of cropland converted to grassland in the U.S. (Ogle et al. 2010). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014), emissions factors for the U.S. (Ogle et al. 2010), and the assumption that herbaceous cover is unfertilized. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

## Contour Buffer Strips
## (Conservation Practice Standard 332)

**NRCS Practice Information**

DEFINITION: Narrow strips of permanent, herbaceous vegetative cover established around the hill slope, and alternated down the slope with wider cropped strips that are farmed on the contour.

PURPOSE:
- Reduce sheet and rill erosion
- Reduce transport of sediment and other water-borne contaminants downslope
- Increase water infiltration

CONDITIONS WHERE PRACTICE APPLIES: This practice applies on all sloping cropland, including orchards, vineyards and nut crops.
- Where the width of the buffer strips will be equal to or exceed the width of the adjoining crop strips, the practice Stripcropping (Conservation Practice Standard 585) applies.


Photo by USDA NRCS

**COMET-Planner Practice Information**

COMET-Planner estimates for contour buffer strip plantings are constructed from the scenario of converting strips of conventionally managed cropland to permanent, unfertilized, herbaceous cover. Impacts on greenhouse gases include changes in soil organic matter carbon due to cessation of tillage and increased inputs from plant residues, and decreased nitrous oxide emissions from synthetic fertilizer.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Contour Buffer Strips (CP 332)** | Dry/semiarid | 1.05 (0.68 – 1.40) | 0.08 (0 – 0.15) | Not estimated |
| | Moist/humid | 0.98 (0.64 – 1.34) | 0.28 (0 – 0.50) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Soil carbon estimates were based on studies of cropland converted to grassland in the U.S. (Ogle et al. 2010). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014), emissions factors for the U.S. (Ogle et al. 2010),and the assumption that herbaceous cover is unfertilized. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

# Field Border
## (Conservation Practice Standard 386)

**NRCS Practice Information**

DEFINITION: A strip of permanent vegetation established at the edge or around the perimeter of a field.

PURPOSE:

- Reduce erosion from wind and water
- Protect soil and water
- Provide wildlife food and cover and pollinator or other beneficial organism
- Increase carbon
- Improve air

CONDITIONS WHERE PRACTICE APPLIES: This practice is applied around the inside perimeter of fields. Its use can support or connect other buffer practices within and between fields. This practice applies to cropland and grazing lands.


Photo by USDA NRCS

**COMET-Planner Practice Information**

COMET-Planner estimates for field border plantings are constructed from the scenario of converting strips of conventionally managed cropland to permanent unfertilized herbaceous cover. Impacts on greenhouse gases include changes in soil organic matter carbon due to cessation of tillage and increased carbon inputs from plant residues, and decreased nitrous oxide from synthetic fertilizer.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Field Border (CP 386)** | Dry/semiarid | 1.05 (0.68 – 1.40) | 0.08 (0 – 0.15) | Not estimated |
| | Moist/humid | 0.98 (0.64 – 1.34) | 0.28 (0 – 0.50) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Soil carbon estimates were based on studies of cropland converted to grassland in the U.S. (Ogle et al. 2010). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014), emissions factors for the U.S. (Ogle et al. 2010), and the assumption that herbaceous cover is unfertilized. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

## Filter Strip
## (Conservation Practice Standard 393)

**NRCS Practice Information**

DEFINITION: A strip or area of herbaceous vegetation that removes contaminants from overland flow.

PURPOSE:

- Reduce suspended solids and associated contaminants in runoff
- Reduce dissolved contaminant loadings in runoff
- Reduce suspended solids and associated contaminants in irrigation tailwater

CONDITIONS WHERE PRACTICE APPLIES: Filter strips are established where environmentally-sensitive areas need to be protected from sediment; other suspended solids and dissolved contaminants in runoff.


Photo by USDA NRCS

**COMET-Planner Practice Information**

COMET-Planner estimates for filter strip plantings are constructed from the scenario of converting strips of conventionally managed cropland to permanent unfertilized herbaceous cover. Impacts on greenhouse gases include changes in soil organic matter carbon due to cessation of tillage and increased carbon inputs from plant residues, and decreased nitrous oxide emissions from synthetic fertilizer.

| **Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions*** | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Filter Strip (CP 393)** | Dry/semiarid | 1.05 (0.68 – 1.40) | 0.08 (0 – 0.15) | Not estimated |
| | Moist/humid | 0.98 (0.64 – 1.34) | 0.28 (0 – 0.50) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Soil carbon estimates were based on studies of cropland converted to grassland in the U.S. (Ogle et al. 2010). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014), emissions factors for the U.S. (Ogle et al. 2010), and the assumption that herbaceous cover is unfertilized. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated*.

## Grassed Waterway
## (Conservation Practice Standard 412)

**NRCS Practice Information**

DEFINITION: A shaped or graded channel that is established with suitable vegetation to carry surface water at a non-erosive velocity to a stable outlet.

PURPOSE:

- To convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding
- To reduce gully erosion
- To protect/improve water quality

CONDITIONS WHERE PRACTICE APPLIES: In areas where added water conveyance capacity and vegetative protection are needed to control erosion resulting from concentrated runoff.

Photo by USDA NRCS

**COMET-Planner Practice Information**

COMET-Planner estimates for grassed waterways are constructed from the scenario of converting strips of conventionally managed cropland to permanent unfertilized herbaceous cover. Impacts on greenhouse gases include changes in soil organic matter carbon due to cessation of tillage and increased carbon inputs from plant residues, and decreased nitrous oxide emissions from synthetic fertilizer.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Grassed Waterway (CP 412)** | Dry/semiarid | 1.05 (0.68 – 1.40) | 0.08 (0 – 0.15) | Not estimated |
| | Moist/humid | 0.98 (0.64 – 1.34) | 0.28 (0 – 0.50) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Soil carbon estimates were based on studies of cropland converted to grassland in the U.S. (Ogle et al. 2010). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014), emissions factors for the U.S. (Ogle et al. 2010), and the assumption that herbaceous cover is unfertilized. Ranges for nitrous oxide were based on range of average fertilizer rates reported. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

# Cropland to Woody Cover

## Conservation Benefits

NRCS Conservation Practices that involve the conversion of conventionally tilled and fertilized annual cropland to woody systems are implemented for a number of purposes that may include the creation of wood products or renewable energy sources, the control of erosion by wind or water, the reduction of chemical runoff and leaching, storage of carbon in biomass and soils, provide or improve wildlife/insect habitat, and to provide living structures that can screen air borne pollution, shelter crops, and manage snow deposition. Additionally, perennial woody cover may have significant potential for carbon storage in woody biomass and soils.

**NRCS CONSERVATION PRACTICES**

TREE/SHRUB ESTABLISHMENT (CP 612)
WINDBREAK/SHELTERBELT ESTABLISHMENT (CP 380)
WINDBREAK/SHELTERBELT RENOVATION (CP 650)
RIPARIAN FOREST BUFFER (CP 391)
HEDGEROW PLANTING (CP 422)
ALLEY CROPPING (CPS 311)
MULTI-STORY CROPPING (CPS 379)

## Greenhouse Gas Emissions

Carbon sequestration rates in conservation cover with trees and shrubs are estimated to be much greater than many other greenhouse gas mitigation options on farms, largely due to the high potential for carbon storage in woody biomass (Shoeneberger 2008). All of the conservation practices presented involve the long-term carbon dioxide uptake from the atmosphere and resultant storage of carbon as woody biomass. Soil carbon is expected to increase in all of these practices in the areas devoted to trees or shrubs due to the cessation of conventional tillage. In addition to reductions in soil disturbance, perennial woody cover enhances carbon inputs to the soil through plant residues. As described under Cropland Management, nitrous oxide emissions from nitrogen fertilizer applications are a major source of greenhouse gas emissions in the U.S. (EPA 2014). Practices that involve full conversion of previously fertilized croplands to perennial woody cover generally do not receive any nitrogen fertilizer additions and therefore have greatly reduced emissions of nitrous oxide. Practices with partial conversion to woody cover, such as alley cropping and multi-story cropping, are assumed to have lower fertilizer inputs than the areas planted to crops, thus reducing nitrous oxide emissions, though not to the extent of those practices with full conversion.

# Tree/Shrub Establishment
# (Conservation Practice Standard 612)

**NRCS Practice Information**

DEFINITION: Establishing woody plants by planting seedlings or cuttings, direct seeding, or natural regeneration.

PURPOSE:

- Forest products such as timber, pulpwood, etc.
- Wildlife habitat
- Long-term erosion control and improvement of water quality
- Treat waste
- Store carbon in biomass
- Reduce energy use
- Develop renewable energy systems
- Improve or restore natural diversity
- Enhance aesthetics

CONDITIONS WHERE PRACTICE APPLIES: Tree/shrub establishment can be applied on any appropriately prepared site where woody plants can be grown.


**COMET-Planner Practice Information**

COMET-Planner estimates for Tree/Shrub Establishment are constructed from a scenario of replacing conventionally managed and fertilized cropland with unfertilized, woody plants. Impacts on greenhouse gases include woody biomass carbon accumulation, change in soil organic matter carbon due to cessation of tillage and increased carbon inputs from plant residues, and decreased nitrous oxide emissions from synthetic fertilizer.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Tree / Shrub Establishment (CPS 612)** | Dry/semiarid | 0.88 (0.47 – 1.29) | 0.08 (0.0 – 0.15) | Not estimated |
| | Moist/humid | 1.98 (1.17 – 3.83) | 0.28 (0.0 – 0.50) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Soil carbon change estimates were derived from reference soil carbon stock values for North America (Eve et al. 2104) and IPCC stock change methodology (IPCC 2006). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014), emissions factors for North America (Ogle et al. 2010), and the assumption that the woody cover is unfertilized. Ranges for nitrous oxide are based on ranges of average fertilizer rates reported in ERS surveys. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

## Windbreak/Shelterbelt Establishment
## (Conservation Practice Standard 380)

**NRCS Practice Information**

DEFINITION: Windbreaks or shelterbelts are single or multiple rows of trees or shrubs in linear configurations.

PURPOSE:
- Increase carbon storage in biomass and soils
- Reduce soil erosion from wind
- Protect plants from wind related damage
- Alter the microenvironment for enhancing plant growth
- Manage snow deposition
- Provide shelter
- Enhance wildlife habitat
- Provide noise and visual screens
- Improve air quality by reducing and intercepting air borne particulate matter, chemicals and odors
- Improve irrigation efficiency

CONDITIONS WHERE PRACTICE APPLIES: Apply this practice on any areas where linear plantings of woody plants are desired and suited for controlling wind, noise, and visual resources.


**COMET-Planner Practice Information**

COMET-Planner estimates for Windbreak/Shelterbelt Establishment are constructed from a scenario of replacing a strip of conventionally managed and fertilized cropland with unfertilized, woody plants. Impacts on greenhouse gases include woody biomass carbon accumulation, changes in soil organic matter carbon due to cessation of tillage and increased carbon inputs from plant residues, and decreased nitrous oxide emissions from synthetic fertilizer. Estimates apply only to the portion of the field where woody plants are established.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2$ eq $ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2$ eq $ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2$ eq $ac^{-1}\ y^{-1}$) Average (Range)** |
| **Windbreak / Shelterbelt Establishment (CPS 380)** | Dry/semiarid | 1.01 (0.37 – 2.93) | 0.08 (0 – 0.15) | Not estimated |
| | Moist/humid | 1.81 (0.89 – 3.60) | 0.28 (0 – 0.50) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Soil carbon change estimates were derived from reference soil carbon stock values for North America (Eve et al. 2014) and IPCC stock change methodology (IPCC 2006). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014), emissions factors for North America (Ogle et al. 2010), and the assumption that the woody cover is unfertilized. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated*.

## Windbreak/Shelterbelt Renovation
## (Conservation Practice Standard 650)

**NRCS Practice Information**

DEFINITION: Replacing, releasing and/or removing selected trees and shrubs or rows within an existing windbreak or shelterbelt, adding rows to the windbreak or shelterbelt or removing selected tree and shrub branches.

PURPOSE: Restoring or enhancing the original planned function of existing windbreaks or shelterbelts.

CONDITIONS WHERE PRACTICE APPLIES: In any windbreak or shelterbelt that is no longer functioning properly for the intended purpose.

Photo by USDA NRCS

**COMET-Planner Practice Information**

COMET-Planner estimates for Windbreak/Shelterbelt Renovation are constructed from a scenario of replacing 50 percent of woody plants in an existing unfertilized windbreak. Impacts on greenhouse gases include new woody biomass carbon sequestration. Estimates apply only to the portion of the field where woody plants are established.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Windbreak / Shelterbelt Establishment (CPS 650)** | Dry/semiarid | 0.21 (0.07 – 1.00) | 0 | Not estimated |
| | Moist/humid | 0.40 (0.12 – 1.08) | 0 | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Effects of replacement on soil organic carbon were not estimated and effects on nitrous oxide emissions were assumed to be negligible. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated*.

## Riparian Forest Buffer Establishment
## (Conservation Practice Standard 391)

### NRCS Practice Information

DEFINITION: An area predominantly trees and/or shrubs located adjacent to and up-gradient from watercourses or water bodies.

PURPOSE:
- Increase carbon storage in plant biomass and soils
- Reduce excess amounts of sediment, organic material, nutrients and pesticides in surface runoff and reduce excess nutrients and other chemicals in shallow ground water flow
- Create or improve riparian habitat and provide a source of detritus and large woody debris
- Reduce pesticide drift entering the water body
- Restore riparian plant communities

CONDITIONS WHERE PRACTICE APPLIES: Riparian forest buffers are applied on areas adjacent to permanent or intermittent streams, lakes, ponds, and wetlands. They are not applied to stabilize stream banks or shorelines.


Photo by USDA NRCS

### COMET-Planner Practice Information

COMET-Planner estimates for Riparian Forest Buffer establishment are constructed from a scenario of replacing conventionally managed and fertilized cropland with unfertilized, woody plants. Impacts on greenhouse gases include woody biomass carbon accumulation, change in soil organic matter carbon due to cessation of tillage and increased carbon inputs from plant residues, and decreased nitrous oxide emissions from synthetic fertilizer.

| **Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions*** | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Riparian Forest Buffer Establishment (CPS 391)** | Dry/semiarid | 1.00 (0.38 – 1.63) | 0.08 (0 – 0.15) | Not estimated |
| | Moist/humid | 2.19 (0.96 – 3.26) | 0.28 (0 – 0.50) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Soil carbon change estimates were derived from reference soil carbon stock values for North America (Eve et al. 2014) and IPCC stock change methodology (IPCC 2006). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA_ERS), emissions factors for North America (Ogle et al. 2010), and the assumption that the woody cover is unfertilized. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated*.

# Hedgerow Planting
## (Conservation Practice Standard 422)

### NRCS Practice Information

DEFINITION: Establishment of dense vegetation in a linear design to achieve a natural resource conservation purpose.

PURPOSE:

- To increase carbon storage in biomass and soils.
- Habitat, including food, cover, and corridors for terrestrial wildlife
- To enhance pollen, nectar, and nesting habitat for pollinators
- To provide substrate for predaceous and beneficial invertebrates as a component of integrated pest management
- To intercept airborne particulate matter
- To reduce chemical drift and odor movement
- Screens and barriers to noise and dust
- Living fences

CONDITIONS WHERE PRACTICE APPLIES: This practice applies wherever it will accomplish at least one of the purposes stated above.


### COMET-Planner Practice Information

COMET-Planner estimates for Hedgerow Planting are constructed from a scenario of replacing conventionally managed and fertilized cropland with unfertilized woody plants. Impacts on greenhouse gases include woody biomass carbon accumulation, change in soil organic matter carbon due to cessation of tillage and increased carbon inputs from plant residues, and decreased nitrous oxide emissions from synthetic fertilizer.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Hedgerow Planting (CPS 422)** | Dry/semiarid | 0.83 (0.47 – 1.17) | 0.08 (0 – 0.15) | Not estimated |
| | Moist/humid | 1.42 (1.06 – 1.89) | 0.28 (0 – 0.50) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Woody biomass carbon estimates are for two-row windbreaks and were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Soil carbon change estimates were derived from reference soil carbon stock values for North America (Eve et al. 2014) and IPCC stock change methodology (IPCC 2006). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014), emissions factors for North America (Ogle et al. 2010), and the assumption that the woody cover is unfertilized. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

# Alley Cropping
## (Conservation Practice Standard 311)

**NRCS Practice Information**

DEFINITION: Trees or shrubs are planted in sets of single or multiple rows with agronomic, horticultural crops or forages produced in the alleys between the sets of woody plants that produce additional products.

PURPOSE:
- Increase carbon storage in plant biomass and soils
- Reduce surface water runoff and erosion
- Improve soil health by increasing utilization and cycling of nutrients
- Alter subsurface water quantity or water table depths
- Enhance wildlife and beneficial insect habitat
- Decrease offsite movement of nutrients or chemicals
- Develop renewable energy systems

CONDITIONS WHERE PRACTICE APPLIES: On all cropland and hayland where trees, shrubs, crops and/or forages can be grown in combination.


Photo by USDA NRCS

**COMET-Planner Practice Information**

COMET-Planner estimates for Alley Cropping are constructed from a scenario of replacing 20 percent of the area of conventionally managed and fertilized cropland with woody plants. Impacts on greenhouse gases include woody biomass carbon accumulation, change in soil organic matter carbon due to cessation of tillage and increased carbon inputs from plant residues, and decreased nitrous oxide from lower synthetic fertilizer.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Alley Cropping (CPS 311)** | Dry/semiarid | 0.80 (0 – 1.62) | 0.01 (0 – 0.01) | Not estimated |
| | Moist/humid | 1.71 (0 – 3.43) | 0.03 (0 – 0.05) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Woody biomass carbon and soil organic carbon estimates were based on a literature review by Nair and Nair (2003). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014), emissions factors for North America (Ogle et al. 2010), and the assumption that the woody cover receives 50% less nitrogen fertilizer than crops. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

## Multistory Cropping
## (Conservation Practice Standard 379)

**NRCS Practice Information**

DEFINITION: Existing or planted stands of trees or shrubs that are managed as an overstory with an understory of woody and/or non-woody plants that are grown for a variety of products.

PURPOSE:

- Increase net carbon storage in plant biomass and soil
- Improve crop diversity by growing mixed but compatible crops having different heights on the same area
- Improve soil quality by increasing utilization and cycling of nutrients and maintaining or increasing soil organic matter

CONDITIONS WHERE PRACTICE APPLIES: On all lands where trees, shrubs, woody or non-woody crops can be grown in combination. The practice does not apply on land that is grazed.

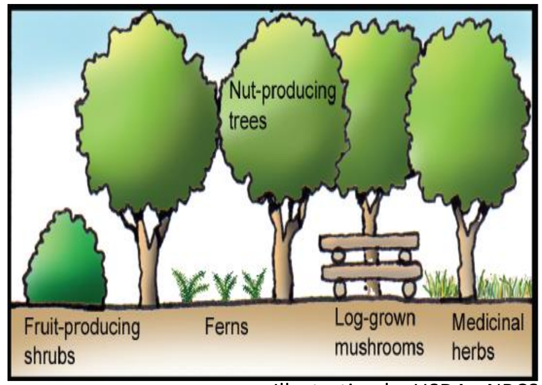

Illustration by USDA - NRCS

**COMET-Planner Practice Information**

COMET-Planner estimates for Multistory Cropping are constructed from the Alley Cropping scenario of replacing 20 percent of the area of conventionally managed and fertilized cropland with woody plants. Impacts on greenhouse gases include woody biomass carbon accumulation, change in soil organic matter carbon due to cessation of tillage, and decreased nitrous oxide emissions from synthetic fertilizer.

| **Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions*** | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Multistory Cropping (CPS 379)** | Dry/semiarid | 0.80 (0 – 1.62) | 0.01 (0 – 0.01) | Not estimated |
| | Moist/humid | 1.71 (0 – 3.43) | 0.03 (0 – 0.05) | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Woody biomass carbon and soil organic carbon estimates for multistory cropping were not available so values for Alley Cropping were used. Woody biomass carbon and soil organic carbon estimates were based on a literature review by Nair and Nair (2003). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014), emissions factors for North America (Ogle et al. 2010), and the assumption that the woody cover receives 50% less nitrogen fertilizer than crops. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated*.

# Grazing Lands

### Conservation Benefits

For NRCS conservation practices on grazing lands, conservation objectives include the provision of improved and sustainable forage/browse, improved soil and water quality, reduced erosion, improved shade for livestock and cover for wildlife, reduce fire hazards, and increase carbon sequestration in biomass and soils. Conservation practices on grazing lands that reduce degradation of soils or improve productivity of grasslands also have potential for greenhouse gas benefits.

> **NRCS CONSERVATION PRACTICES**
>
> RANGE PLANTING (CPS 550)
> SILVOPASTURE ESTABLISHMENT ON GRAZED GRASSLAND (CPS 381)
> PRESCRIBED GRAZING (CPS 528)

### Greenhouse Gas Emissions

Grazing lands comprise 35 percent of all U.S. land area and about two-thirds of all agricultural land use, thus represent a large potential sink of carbon (CAST 2011). Practices that decrease biomass removal by reducing the number of animals grazing such as **prescribed grazing**, or that increase forage production while holding animal numbers steady, such as **range planting**, will tend to increase carbon sequestration in the soil. Carbon sequestration potential following pasture and grazing management improvements is especially high in grazing lands that have been previously degraded due to long-term overgrazing (Conant and Paustian 2002). The planting of trees or shrubs on grazing land (**silvopasture establishment**) will introduce long-term carbon storage in woody biomass.

# Range Planting
## (Conservation Practice Standard 550)

**NRCS Practice Information**

DEFINITION: Establishment of adapted perennial or self-sustaining vegetation such as grasses, forbs, legumes, shrubs and trees.

PURPOSE:

- Restore a plant community similar to the Ecological Site Description reference state for the site or the desired plant community
- To improve the energy efficiency of agricultural combustion systems
- Provide or improve forages for livestock
- Reduce erosion by wind and/or water
- Improve water quality and quantity
- Increase carbon sequestration

CONDITIONS WHERE PRACTICE APPLIES: On rangeland, native or naturalized pasture, grazed forest or other suitable location where the principle goals and method of vegetation management is herbivore based. This practice shall be applied where desirable vegetation is below the acceptable level for natural reseeding to occur, or where the potential for enhancement of the vegetation by grazing management is unsatisfactory.


Photo by CSU

**COMET-Planner Practice Information**

COMET-Planner estimates assume that grasslands were restored from degraded to native conditions, or were seeded with improved forages. Enhanced productivity of improved grasslands is expected to increase soil carbon stocks, through higher inputs of carbon from plant residues.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Range Planting** | Dry/semiarid | 0.34 (0.15 – 0.73) | Not estimated | Not estimated |
| | Moist/humid | 0.50 (0.30 – 0.78) | Not estimated | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Limited data was available on the influence of range planting in recent reviews. Emissions reductions were estimated using the Intergovernmental Panel on Climate Change (IPCC) inventory method (IPCC 2006) for grasslands and evaluated as an average of a change from moderately degraded to nominal condition or from nominal to improved condition, with factors provided in Eve et al. (2014). Reference soil carbon stocks were from Eve et al. (2014) and estimated stock changes were area-weighted using total IPCC soil areas classified from SSURGO soils data, by IPCC climate regions (IPCC 2006, Soil Survey Staff 2011). *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

## Silvopasture Establishment on Grazed Grasslands
## (Conservation Practice Standard 381)

**NRCS Practice Information**

DEFINITION: An application establishing a combination of trees or shrubs and compatible forages on the same acreage.

PURPOSE:
- Provide forage for livestock and the production of wood products
- Increase carbon sequestration
- Improve water quality
- Reduce erosion
- Enhance wildlife habitat
- Reduce fire hazard
- Provide shade for livestock
- Develop renewable energy systems

CONDITIONS WHERE PRACTICE APPLIES: Situations where silvopasture establishment applies includes: 1) pasture where trees or shrubs can be added; 2) forest where forages can be added; 3) Land on which neither the desired trees nor forages exist in sufficient quantity to meet the land user's objectives. This practice may be applied on any area that is suitable for the desired plants.

**COMET-Planner Practice Information**

COMET-Planner estimates for silvopasture establishment on grazed grassland are constructed from a scenario of tree/shrub planting on existing unfertilized grazing land. Soil organic carbon is assumed to remain essentially unchanged.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Silvopasture Establishment on Grazed Grasslands (CP 381)** | Dry/semiarid | 0.66 (0.46 – 0.91) | Not estimated | Not estimated |
| | Moist/humid | 1.34 (0.94 – 1.86) | Not estimated | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Soil C changes were not estimated. No estimates were available for dry/semiarid climates. Dry/semiarid climate values were estimated as 49% of the rate for Moist/humid climates. The value of 49% is the average ratio between climates for total carbon changes for windbreak, riparian buffers and farm woodlots. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

## Prescribed Grazing
## (Conservation Practice Standard 528)

**NRCS Practice Information**
DEFINITION: Managing the harvest of vegetation with grazing and/or browsing animals.

PURPOSE:
- Improve or maintain desired species composition and vigor of plant communities
- Improve or maintain quantity and quality of forage for grazing and browsing animals' health and productivity
- Improve or maintain surface and/or subsurface water quality and quantity
- Improve or maintain riparian and watershed function
- Reduce accelerated soil erosion, and maintain or improve soil condition
- Improve or maintain the quantity and quality of food and/or cover available for wildlife
- Manage fine fuel loads to achieve desired conditions

CONDITIONS WHERE PRACTICE APPLIES: This practice applies to all lands where grazing and/or browsing animals are managed.


Photo by USDA NRCS

**COMET-Planner Practice Information**
COMET-Planner estimates assume that grasslands were previously overgrazed, leading to degradation and decreased soil carbon stocks. Prescribed grazing practices are assumed to improve grassland condition and productivity, which is expected to increase soil carbon stocks.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Prescribed Grazing** | Dry/semiarid | 0.18 (0.08 – 0.38) | Not estimated | Not estimated |
| | Moist/humid | 0.26 (0.16 – 0.41) | Not estimated | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Limited data was available on the influence of prescribed grazing in recent reviews. Emissions reductions from soil carbon were estimated using the Intergovernmental Panel on Climate Change (IPCC) inventory method (IPCC 2006) for grasslands and evaluated as a change from moderately degraded to nominal condition, with factors from Eve et al. (2014). Reference soil carbon stocks were from Eve et al. (2014) and estimated stock changes were area-weighted using total IPCC soil areas classified from SSURGO soils data, by IPCC climate regions (IPCC 2006, Soil Survey Staff 2011). *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

# Restoration of Disturbed Lands

## Conservation Benefits

> **NRCS CONSERVATION PRACTICES**
>
> LAND RECLAMATION – ABANDONED MINE LAND (CPS 543)
> LAND RECLAMATION – CURRENTLY MINED LAND (CPS 544)
> LAND RECLAMATION – LANDSLIDE TREATMENT (CPS 453)
> CRITICAL AREA PLANTING (CPS 342)
> RIPARIAN RESTORATION

NRCS conservation practices for land restoration have the objectives of reclamation of land adversely affected by natural disaster and by the activities of industry. These practices seek to stabilize disturbed areas to decrease erosion and sedimentation, rehabilitate with desirable vegetation; improve offsite water quality and or quantity, provide safety, and enhance landscape visual and functional quality. Rehabilitation of disturbed lands may have additional benefits of reducing greenhouse gas emissions and sequestering atmospheric carbon.

## Greenhouse Gas Emissions

Disturbed lands are lands that have been stripped in part or entirely of vegetative cover and where soil disturbance is extreme or where soil loss has been excessive. The consequences of physical disturbance to the top soil cause unusually large N transformations and movements with substantial loss. Management of top soil is important for reclamation plan to reduce the N losses and to increase soil nutrients and microbes (Sheoran et al. 2010). Success in the reclamation of disturbed sites, especially when the topsoil has been lost or discarded, depends on the rapid formation of surface soil containing high SOM content (Tate et al. 1987).

Losses of soil organic carbon have been estimated at 80 percent of native levels in mine soils (Ussiri and Lal 2005). Reclamation is an essential part in developing mineral resources in accordance with the principles of ecologically sustainable development (Sheoran et al. 2010). Restoring vegetation to these lands can sequester carbon long-term in biomass if planted to woody systems (EPA-OSRTI 2012) and can sequester carbon in the soil through carbon inputs from plant residues in both woody and herbaceous plantings (Akala and Lal 2000). Successful revegetation and subsequent carbon sequestration in surface mine soils require careful management of soil (physical, chemical, and biological) and vegetation parameters (species selection, seedbed preparation, seeding rates, time of seeding, the appropriate use of amendments in order to assure vegetative establishment) (Brown and Song 2006; Akala and Lal 2000).

Vegetation can protect critical areas such as coastline and stream bank slopes and inhibit landslides by reducing erosion, and strengthening soil. The use of vegetation to manage erosion and protect slopes is relatively inexpensive, does not require heavy machinery on the slope, establishes wildlife habitat, and can improve the aesthetic quality of the property (Myers 1993).

## Land Reclamation – Abandoned Mine Land
## (Conservation Practice Standard 543)

**NRCS Practice Information**

DEFINITION: Reclamation of land and water areas adversely affected by past mining activities

PURPOSE:

- Stabilize abandoned mined areas to decrease erosion and sedimentation, support desirable vegetation and improve offsite water quality and or quantity
- Maintain or improve landscape visual and functional quality
- Protect public health, safety and general welfare

CONDITIONS WHERE PRACTICE APPLIES: This practice applies to abandoned mined land that degrades the quality of the environment and prevents or interferes with the beneficial uses of soil, water, air, plant or animal resources, or endangers human health and safety.


**COMET-Planner Practice Information**

COMET-Planner estimates for reclamation of mined land are constructed from two scenarios. For dry/semiarid climate the assumption is herbaceous planting and soil carbon changes are estimated using cropland set-aside literature. For moist/humid climate the assumption is woody planting and biomass carbon sequestration and soil carbon changes were estimated using values from tree/shrub establishment.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2$ eq $ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2$ eq $ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2$ eq $ac^{-1}\ y^{-1}$) Average (Range)** |
| **Land Reclamation – Abandoned Mine Land (CP 543)** | Dry/semiarid | 1.05 (0.68 – 1.40) | Not estimated | Not estimated |
| | Moist/humid | 1.90 (1.02 – 3.65) | Not estimated | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. In moist/humid climates, woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Only herbaceous planting was assumed for dry/semiarid climate. Soil organic carbon estimates were based on North America sandy soils (Eve et al. 2014) substituting for disturbed soils. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

# Land Reclamation – Currently Mined Land
## (Conservation Practice Standard 544)

**NRCS Practice Information**

DEFINITION: Reclamation of currently mined land to an acceptable form and planned use.

PURPOSE:
- Prevent negative impacts to soil, water and air resources in and near mined areas
- Restore the quality of the soils to their premining level
- Maintain or improve landscape visual and functional quality

CONDITIONS WHERE PRACTICE APPLIES:
This practice applies to currently mined land. It includes the identification, removal, stockpiling and replacement of soil materials, and revegetation. This practice also applies to nearby non-mined areas adversely affected by the mining activities.


**COMET-Planner Practice Information**

COMET-Planner estimates for reclamation of mined land are constructed from two scenarios. For dry/semiarid climates, the assumption is herbaceous planting and soil carbon changes are estimated using cropland set-aside literature. For moist/humid climate, the assumption is woody planting and biomass carbon sequestration and soil carbon changes were estimated using values from tree/shrub establishment.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2$ eq $ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2$ eq $ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2$ eq $ac^{-1}\ y^{-1}$) Average (Range)** |
| **Land Reclamation – Currently Mined Land (CP 544)** | Dry/semiarid | 1.05 (0.68 – 1.40) | Not estimated | Not estimated |
| | Moist/humid | 1.90 (1.02 – 3.65) | Not estimated | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. In moist/humid climates, woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Only herbaceous planting was assumed for dry/semiarid climates. Soil organic carbon estimates were based on North America sandy soils (Eve et al. 2014) as a proxy for disturbed soils. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated*.

## Land Reclamation – Landslide Treatment
## (Conservation Practice Standard 453)

**NRCS Practice Information**

DEFINITION

Managing in-place natural materials, mine spoil (excavated over-burden), mine waste or overburden to reduce down-slope movement.

PURPOSE:

- Repair unstable slopes caused by slope failure, and reduce the likelihood of enlargement or renewed movement of slope surfaces
- Protect life and property
- Prevent excessive erosion and sedimentation
- Improve water quality and landscape resource quality
- Create a condition conducive to establishing surface protection and beneficial land use

CONDITIONS WHERE PRACTICE APPLIES

To areas where in-place material, mine spoil, waste, or overburden, or rock cut road banks are unstable, moving, or judged to have potential of moving down slope in a manner that will cause damage to life, property, or the environment.


Photo by USDA NRCS

**COMET-Planner Practice Information**

COMET-Planner estimates for landslide treatment are constructed from the scenario of woody planting. Biomass carbon sequestration and soil carbon changes were estimated using values from tree/shrub establishment.

| **Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions*** | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Land Reclamation – Landslide Treatment (CP 453)** | Dry/semiarid | 0.73 (0.47 – 1.09) | Not estimated | Not estimated |
| | Moist/humid | 1.90 (1.02 – 3.65) | Not estimated | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. In moist/humid climates, woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Only herbaceous planting was assumed for dry/semiarid climates. Soil organic carbon estimates were based on North America sandy soils (Eve et al. 2014) as a proxy for disturbed soils. Effects on emissions from site preparation prior to planting were not estimated. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated*.

## Critical Area Planting
## (Conservation Practice Standard 342)

### NRCS Practice Information

DEFINITION: Establishing permanent vegetation on sites that have, or are expected to have, high erosion rates, and on sites that have physical, chemical or biological conditions that prevent the establishment of vegetation with normal practices.

PURPOSE:

- Stabilize stream and channel banks, and shorelines
- Stabilize areas with existing or expected high rates of soil erosion by wind or water
- Rehabilitate and revegetate degraded sites that cannot be stabilized using normal establishment techniques
- Stabilize coastal areas, such as sand dunes and riparian areas

CONDITIONS WHERE PRACTICE APPLIES: This practice applies to highly disturbed areas such as:
active or abandoned mined lands; urban conservation sites; road construction areas; conservation practice construction sites; areas needing stabilization before or after natural disasters; eroded banks of natural channels, banks of newly constructed channels, and lake shorelines; other areas degraded by human activities or natural events.

Photo by USDA NRCS

### COMET-Planner Practice Information

COMET-Planner estimates for critical area planting are constructed from two scenarios. For dry/semiarid climates, the assumption is herbaceous planting and soil carbon changes are estimated using cropland set-aside literature. For moist/humid climates, the assumption is woody planting and biomass carbon sequestration and soil carbon changes were estimated using values from tree/shrub establishment.

| Approximate Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Critical Area Planting (CP 342)** | Dry/semiarid | 1.05 (0.68 – 1.40) | Not estimated | Not estimated |
| | Moist/humid | 1.90 (1.02 – 3.65) | Not estimated | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. In moist/humid climates, woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Only herbaceous planting was assumed for dry/semiarid climate. Soil organic carbon estimates were based on North America sandy soils (Eve et al. 2014) as a proxy for disturbed soils. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

## Riparian Restoration
### (NRCS Program)

**NRCS Practice Information**

When a riparian system is degraded, heavy runoff moves through the riparian zone directly into river channels. Fine sediments eventually fill up stream pools, altering the shape of the stream channels and covering rocky stream bottoms, thereby impairing important food-producing, shelter, and spawning areas. Runoff can bring seeds of nonnative and nonriparian plant species, reducing habitat for native species, and the water table can be lowered by crowding out more native riparian species. Degradation of the native plant community can create a fire risk by increasing fuel loads. Furthermore, streamsides lose their ability to buffer and protect streams, resulting in damage to aquatic habitat, increased costs for treating drinking water, and loss of aesthetic appeal. *(Machtinger 2007)*


Photo by USDA NRCS

**COMET-Planner Practice Information**

COMET-Planner estimates for riparian area restoration are constructed from a scenario of woody plantings on degraded streambanks. Impacts on greenhouse gases include woody biomass carbon accumulation and changes in soil organic matter carbon due to increased carbon inputs from plant residues.

| Approximately Carbon Sequestration and Greenhouse Gas Emission Reductions* | | | | |
|---|---|---|---|---|
| **Practice** | ***Climate zone*** | **Carbon Dioxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Nitrous Oxide ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** | **Methane ($Mg\ CO_2\ eq\ ac^{-1}\ y^{-1}$) Average (Range)** |
| **Riparian Restoration** | Dry/semiarid | 1.00 (0.38 – 1.63) | Not estimated | Not estimated |
| | Moist/humid | 2.19 (0.96 – 3.26) | Not estimated | Not estimated |

*Positive values indicate reductions in greenhouse gas emissions and negative values indicate increases in greenhouse gas emissions. Woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Soil carbon estimates were derived from carbon stock values from Eve at al. 2014 (HAC, LAC, and sandy soils) and IPCC 2006 stock change methodology. *These estimates are not meant to apply to any specific site conditions but rather represent the range of expected values to be found over broadly defined climate regions and conditions and reflect the assumptions stated.*

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# APPENDIX I

Emission reduction coefficients were derived from recent meta-analyses and literature reviews. Coefficients were generalized at the national-scale and differentiated by dry and humid climate zones. Ranges for emission coefficients generally represent minimum and maximum values reported in meta-analyses and literature reviews. When ranges were not given, minimum and maximum values were calculated as +/- 100% of the average emission coefficient. Emission coefficients, ranges, a short explanation of estimation methods, and primary sources are presented in the following tables. Note that values are **emission reductions** relative to baseline management, **thus negative values denote an increase in emissions due to the implementation of a conservation practice**.

***Emission coefficients were derived for the following broad NRCS practice categories:***

CROPLAND MANAGEMENT
CROPLAND TO HERBACEOUS COVER
CROPLAND TO WOODY COVER
GRAZING LANDS
RESTORATION OF DISTURBED LANDS

| CROPLAND MANAGEMENT | | | | | | |
|---|---|---|---|---|---|---|
| **Practice** **(Conservation Practice Standard Number)** | ***Climate zone**** | **Carbon Dioxide** *Average (Range)* | **Nitrous Oxide** *Average (Range)* | **Methane** *Average (Range)* | **Explanation and Notes** | **Primary Sources** |
| | | **Mg $CO_2$ eq acre$^{-1}$ y$^{-1}$** | | | | |
| **Conventional Tillage to No Till (CPS 329)** | Dry/ semiarid | 0.23 (0.02 – 0.54) | 0.13 (0.06 – 0.20) | Not estimated | Carbon estimates represent averages of soil carbon change from recent reviews. The highest values for soil carbon were in corn systems with means of 0.42 and 0.60 Mg $CO_2$ eq acre$^{-1}$ y$^{-1}$ in dry and humid climates respectively. Estimates for nitrous oxide emissions represent the effects of changing tillage only and assume N fertilizer rates do not change (Swan et al.). | Eagle et al. 2012, ICF International 2013, Ogle et al. 2010, Swan et al. (in prep) |
| | Moist/ humid | 0.42 (0.13 – 0.77) | -0.11 (-0.16 – -0.08) | Not estimated | | |
| **Conventional Tillage to Reduced Till (CPS 345)** | Dry/ semiarid | 0.10 (0.04 – 0.19) | 0.07 (0 – 0.15) | Not estimated | Carbon estimates represent averages of soil carbon change from recent reviews. Highest values for soil carbon were in corn systems with means of 0.16 and 0.14 Mg $CO_2$ eq acre$^{-1}$ y$^{-1}$ in dry and humid climates respectively. Nitrous oxide emission changes were from Eagle et al. (2012). Nitrous oxide range is +/- 100% of reported value. | Eagle et al. 2012, ICF International 2013, Ogle et al. 2010 |
| | Moist/ humid | 0.13 (0.02 – 0.22) | 0.07 (0 – 0.15) | Not estimated | | |
| **Nutrient Management - Improved Nitrogen Fertilizer Management (CPS 590)** | Dry/ semiarid | Not estimated | 0.04 (0 – 0.05) | Not estimated | Improved nitrogen management represents the combined mitigation potential of a 15% N rate reduction, use of nitrification inhibitors and a shift from fall to spring N application. Average fertilizer rates by major crop types (USDA-ERS 2014) represented baseline emissions, to which a 15% rate reduction was applied. Average N rates were area-weighted by crop types within climate zones. Nitrous oxide | Akiyama et al. 2010, ICF International 2013, Ogle et al. 2010, USDA-ERS 2014, USDA-NASS 2012 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Moist/ humid | Not estimated | 0.11 (0 – 0.14) | Not estimated | emission rates were based on Ogle et al. (2010) emission factors, and emissions reduction from nitrification inhibitors were based on an average of emission reductions from Ogle et al. (2010) and Akiyama et al. (2010). Emissions reductions from a switch from fall to spring N application were from ICF International (2013) and area-weighted by major crop types (USDA-NASS 2012) within climate zones. | |
| **Nutrient Management – Replacing Synthetic Nitrogen Fertilizer with Soil Amendments (CPS 590)** | Dry/ semiarid | 1.00 (0.40 – 2.17) | Not estimated | Not estimated | Emissions reductions for soil carbon were estimated using the Intergovernmental Panel on Climate Change (IPCC) inventory method for annual cropland, using the emission factors for high input with amendment (dry = 1.34, humid = 1.38) from Eve et al. (2014). Reference soil carbon stocks were from Eve et al. (2014) and estimated stock changes were area-weighted using total IPCC soil areas classified from SSURGO soils data, by IPCC climate regions (IPCC 2006, Soil Survey Staff 2011). | Eve et al. 2014, IPCC 2006, Soil Survey Staff 2011 |
| | Moist/ humid | 1.75 (0.85 – 2.51) | Not estimated | Not estimated | | |
| **Conservation Crop Rotation (CPS 328)** | Dry/ semiarid | 0.26 (-0.18 – 0.71) | 0 (-0.02 – 0.02) | Not estimated | Values for dry climates were averaged from soil carbon sequestration rates from eliminating summer fallow (Eagle et al. 2012, Sherrod et al. 2003) and adding perennial crops to rotations (Eagle et al. 2012). Nitrous oxide emissions from these practices average to zero, since increased cropping intensity may lead to an increase in N application, whereas perennial crops in rotation likely result in a decrease in N fertilization. Values for soil carbon and nitrous oxide for humid climates were based on estimates for adding perennial crops to annual crop rotations (Eagle et al. 2012). | Eagle et al. 2012, Sherrod et al. 2003 |
| | Moist/ humid | 0.21 (0.0 – 0.49) | 0.01 (0 – 0.02) | Not estimated | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Cover Crops (CPS 340)** | Dry/ semiarid | 0.21 (0.08 – 0.45) | 0.05 (0.0 – 0.10) | Not estimated | Limited data was available on the influence of cover crops in recent reviews. Emissions reductions for soil carbon were estimated using the Intergovernmental Panel on Climate Change (IPCC) inventory method for annual cropland, using the emission factors for high input without amendment (dry & humid = 1.07) from Eve et al. (2014). Reference soil carbon stocks were from Eve et al. (2014) and estimated stock changes were area-weighted using total IPCC soil areas classified from SSURGO soils data, by IPCC climate regions (IPCC 2006, Soil Survey Staff 2011). Nitrous oxide emissions changes were from Eagle et al. (2012). | Eagle et al. 2012, Eve et al. 2014, IPCC 2006, Soil Survey Staff 2011 |
| | Moist/ humid | 0.32 (0.16 – 0.46) | 0.05 (0.0 – 0.10) | Not estimated | | |
| **Stripcropping (CPS 585)** | Dry/ semiarid | 0.11 (0 – 0.24) | 0.05 (0.02 – 0.22) | Not estimated | Stripcropping is assumed to include dense grasses or legumes, hay crops or other perennial cover in strips. Therefore mitigation was estimated as half the rate of soil carbon sequestration for perennials in rotation (Eagle et al. 2012). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014), emissions factors for the U.S. (Ogle et al. 2010), and the assumption that rates are reduced by 50% on perennial strips. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported. | Eagle et al. 2012, Ogle et al. 2010, USDA-ERS 2014 |
| | Moist/ humid | 0.11 (0 – 0.24) | 0.13 (0.06 – 0.58) | Not estimated | | |
| **Mulching (CPS 484)** | Dry/ semiarid | 0.21 (0.08 – 0.45) | Not estimated | Not estimated | Limited data was available on the influence of mulching in recent reviews. Emissions reductions for soil carbon were estimated using the Intergovernmental Panel on Climate Change (IPCC) inventory method for annual cropland, using the emission factors for high input without amendment (dry & humid = 1.07) from Eve et al. (2014). Reference soil carbon stocks were from Eve et al. (2014) and estimated stock changes were area-weighted using total IPCC soil areas classified from SSURGO soils data, by IPCC climate regions (IPCC 2006, Soil Survey Staff 2011). | Eve et al. 2014, IPCC 2006, Soil Survey Staff 2011 |
| | Moist/ humid | 0.32 (0.16 – 0.46) | Not estimated | Not estimated | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Combustion System Improvement (Improved Fuel Efficiency of Farm Equipment) (CPS 372)** | Dry/ semiarid | 0.01 (0 – 0.02) | Not estimated | Not estimated | For the purpose of this tool, only improvements in energy efficiency from farm machinery were analyzed. Total emissions from common tillage operations from West and Marland (2002) were area-weighted by total area of tillage systems (CTIC 2008). Emissions estimates were then reduced by 15% to represent a 15% improvement in fuel efficiency. | CTIC 2008, West and Marland 2002 |
| | Moist/ humid | 0.01 (0 – 0.02) | Not estimated | Not estimated | | |

* Climate designations are based on Intergovernmental Panel on Climate Change climate classifications (IPCC 2006). In dry/semiarid climates, annual potential evapotranspiration exceeds annual precipitation; in moist/humid climates annual precipitation exceeds annual potential evapotranspiration.

| Cropland to Herbaceous Cover | | | | | | |
|---|---|---|---|---|---|---|
| **Practice** (Conservation Practice Standard Number) | ***Climate zone**** | **Carbon Dioxide** *Average (Range)* | **Nitrous Oxide** *Average (Range)* | **Methane** *Average (Range)* | **Explanation and Notes** | **Primary Sources** |
| | | **Mg $CO_2$ eq acre$^{-1}$ y$^{-1}$** | | | | |
| **Conservation Cover - Retiring Marginal Soils and Establishing Permanent Grass Cover (CPS 327)** | Dry/ semiarid | 1.05 (0.68 – 1.40) | 0.08 (0.0 – 0.15) | Not estimated | Soil carbon estimates were based on studies of cropland converted to grassland in the U.S. (Ogle et al. 2010). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014) and emissions factors from Ogle et al. (2010), and the assumption that herbaceous cover is unfertilized. Ranges for nitrous oxide were based on the range of average fertilizer rates reported in ARMS (USDA-ERS 2014). | Ogle et al. 2010, USDA-ERS 2014 |
| | Moist/ humid | 0.98 (0.64 – 1.34) | 0.28 (0.0 – 0.50) | Not estimated | | |
| **Forage and Biomass Plantings – Full Conversion (CPS 512)** | Dry/ semiarid | 0.27 (-0.35 – 0.81) | 0.10 (0.0 – 0.19) | Not estimated | Carbon estimates represent soil carbon change as reported in Eagle et al. (2012). Reductions in nitrous oxide were based on assumptions of lower nitrogen fertilizer and/or introduction of legume forages. Nitrous oxide ranges are +/- 100% of value reported. | Eagle et al. 2012 |
| | Moist/ humid | 0.27 (-0.35 – 0.81) | 0.10 (0 – 0.19) | Not estimated | | |
| **Forage and Biomass Plantings – Partial Conversion (CPS 512)** | Dry/ semiarid | 0.21 (0 – 0.49) | 0.01 (0 – 0.02) | Not estimated | Carbon estimates represent soil carbon change as reported in Eagle et al. (2012). Reductions in nitrous oxide were based on assumptions of lower nitrogen fertilizer and/or introduction of legume forages. Nitrous oxide ranges are +/- 100% of value reported. | Eagle et al. 2012 |
| | Moist/ humid | 0.21 (0 – 0.49) | 0.01 (0 – 0.02) | Not estimated | | |
| **Herbaceous Wind Barriers (CPS 603)** | Dry/ semiarid | 1.05 (0.68 – 1.40) | 0.08 (0 – 0.15) | Not estimated | Soil carbon estimates were based on studies of cropland converted to grassland in the U.S. (Ogle et al. 2010). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014) and emissions factors from Ogle et al. (2010), and the assumption that herbaceous cover is unfertilized. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported in ARMS (USDA-ERS 2014). | Ogle et al. 2010, USDA-ERS 2014 |
| | Moist/ humid | 0.98 (0.64 – 1.34) | 0.28 (0 – 0.50) | Not estimated | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Vegetative Barriers (CPS 601)** | Dry/ semiarid | 1.05 (0.68 – 1.40) | 0.08 (0 – 0.15) | Not estimated | Soil carbon estimates were based on studies of cropland converted to grassland in the U.S. (Ogle et al. 2010). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014) and emissions factors from Ogle et al. (2010), and the assumption that herbaceous cover is unfertilized. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported in ARMS (USDA-ERS 2014). | Ogle et al. 2010, USDA-ERS 2014 |
| | Moist/ humid | 0.98 (0.64 – 1.34) | 0.28 (0 – 0.50) | Not estimated | | |
| **Riparian Herbaceous Cover (CPS 390)** | Dry/ semiarid | 1.05 (0.68 – 1.40) | 0.08 (0 – 0.15) | Not estimated | Soil carbon estimates were based on studies of cropland converted to grassland in the U.S. (Ogle et al. 2010). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014) and emissions factors from Ogle et al. (2010), and the assumption that herbaceous cover is unfertilized. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported in ARMS (USDA-ERS 2014). | Ogle et al. 2010, USDA-ERS 2014 |
| | Moist/ humid | 0.98 (0.64 – 1.34) | 0.28 (0 – 0.50) | Not estimated | | |
| **Contour Buffer Strips (CPS 332)** | Dry/ semiarid | 1.05 (0.68 – 1.40) | 0.08 (0 – 0.15) | Not estimated | Soil carbon estimates were based on studies of cropland converted to grassland in the U.S. (Ogle et al. 2010). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014) and emissions factors from Ogle et al. (2010), and the assumption that herbaceous cover is unfertilized. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported in ARMS (USDA-ERS 2014). | Ogle et al. 2010, USDA-ERS 2014 |
| | Moist/ humid | 0.98 (0.64 – 1.34) | 0.28 (0 – 0.50) | Not estimated | | |
| **Field Border (CPS 386)** | Dry/ semiarid | 1.05 (0.68 – 1.40) | 0.08 (0 – 0.15) | Not estimated | Soil carbon estimates were based on studies of cropland converted to grassland in the U.S. (Ogle et al. 2010). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014) and emissions factors from Ogle et al. (2010), and the assumption that herbaceous cover is unfertilized. Ranges for nitrous oxide were based on ranges of | Ogle et al. 2010, USDA-ERS 2014 |
| | Moist/ humid | 0.98 (0.64 – 1.34) | 0.28 (0 – 0.50) | Not estimated | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | average fertilizer rates reported in ARMS (USDA-ERS 2014). | |
| **Filter Strip (CPS 393)** | Dry/ semiarid | 1.05 (0.68 – 1.40) | 0.08 (0 – 0.15) | Not estimated | Soil carbon estimates were based on studies of cropland converted to grassland in the U.S. (Ogle et al. 2010). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014) and emissions factors from Ogle et al. (2010), and the assumption that herbaceous cover is unfertilized. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported in ARMS (USDA-ERS 2014). | Ogle et al. 2010, USDA-ERS 2014 |
| | Moist/ humid | 0.98 (0.64 – 1.34) | 0.28 (0 – 0.50) | Not estimated | | |
| **Grassed Waterway (CPS 412)** | Dry/ semiarid | 1.05 (0.68 – 1.40) | 0.08 (0 – 0.15) | Not estimated | Soil carbon estimates were based on studies of cropland converted to grassland in the U.S. (Ogle et al. 2010). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014) and emissions factors from Ogle et al. (2010), and the assumption that herbaceous cover is unfertilized. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported in ARMS (USDA-ERS 2014). | Ogle et al. 2010, USDA-ERS 2014 |
| | Moist/ humid | 0.98 (0.64 – 1.34) | 0.28 (0 – 0.50) | Not estimated | | |

* Climate designations are based on Intergovernmental Panel on Climate Change climate classifications (IPCC 2006). In dry/semiarid climates, annual potential evapotranspiration exceeds annual precipitation; in moist/humid climates annual precipitation exceeds annual potential evapotranspiration.

| Cropland to Woody Cover | | | | | | |
|---|---|---|---|---|---|---|
| **Practice** (Conservation Practice Standard Number) | ***Climate zone**** | **Carbon Dioxide** *Average (Range)* | **Nitrous Oxide** *Average (Range)* | **Methane** *Average (Range)* | **Explanation and Notes** | **Primary Sources** |
| | | **Mg $CO_2$ eq acre$^{-1}$ y$^{-1}$** | | | | |
| **Tree/Shrub Establishment - Farm Woodlot (CPS 612)** | Dry/ semiarid | 0.88 (0.47 – 1.29) | 0.08 (0 – 0.15) | Not estimated | Woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Soil organic carbon estimates were derived using reference soil carbon stock values from Eve at al. 2014 (HAC, LAC, and sandy soils) and IPCC (2006) stock change methodology. Nitrous oxide estimates were based on weighted average fertilizer rates for major crops, emissions factors from Ogle et al. (2010), and the assumption that woody cover is unfertilized. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported in ARMS (USDA-ERS 2014). | Eve et al. 2014, IPCC 2006, Merwin et al. 2009, Ogle et al. 2010, Paustian et al. 2012 |
| | Moist/ humid | 1.98 (1.17 – 3.83) | 0.28 (0 – 0.50) | Not estimated | | |
| **Windbreak/ Shelterbelt Establishment (CPS 380)** | Dry/ semiarid | 1.01 (0.37 – 2.93) | 0.08 (0 – 0.15) | Not estimated | Woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Soil organic carbon estimates were derived using reference soil carbon stock values from Eve at al. 2014 (HAC, LAC, and sandy soils) and IPCC 2006 stock change methodology. Nitrous oxide | Eve et al. 2014, IPCC 2006, Merwin et al. 2009, Ogle et al. 2010, Paustian et al. 2012 |
| | Moist/ humid | 1.81 (0.89 – 3.60) | 0.28 (0 – 0.50) | Not estimated | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | estimates were based on weighted average fertilizer rates for major crops, emissions factors from Ogle et al. (2010), and the assumption that the woody cover is unfertilized. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported in ARMS (USDA-ERS 2014). | |
| **Windbreak/ Shelterbelt Renovation (CPS 650)** | Dry/ semiarid | 0.21 (0.07 – 1.00) | Not estimated | Not estimated | Carbon estimates are for biomass only with the assumption of a 50% replacement of trees. Soil organic carbon changes were not estimated but assumed to be small. Woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). | Merwin et al. 2009, Paustian et al. 2012 |
| | Moist/ humid | 0.40 (0.12 – 1.08) | Not estimated | Not estimated | | |
| **Riparian Forest Buffer Establishment (CPS 391)** | Dry/ semiarid | 1.00 (0.38 – 1.63) | 0.08 (0 – 0.15) | Not estimated | Woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Soil organic carbon estimates were derived using reference soil carbon stock values from Eve at al. 2014 (HAC, LAC, and sandy soils) and IPCC 2006 stock change methodology. Nitrous oxide estimates were based on weighted average fertilizer rates for major crops, emissions factors from Ogle et al. 2010, and the assumption that the woody cover is unfertilized. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported in ARMS (USDA-ERS 2014). | Eve et al. 2014, IPCC 2006, Merwin et al. 2009, Ogle et al. 2010, Paustian et al. 2012 |
| | Moist/ humid | 2.19 (0.96 – 3.26) | 0.28 (0 – 0.50) | Not estimated | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Hedgerow Planting (CPS 422)** | Dry/ semiarid | 0.83 (0.47 – 1.17) | 0.08 (0 – 0.15) | Not estimated | Woody biomass carbon estimates are for two-row windbreaks and were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Soil organic carbon estimates were derived using reference soil carbon stock values from Eve at al. 2014 (HAC, LAC, and sandy soils) and IPCC 2006 stock change methodology. Nitrous oxide estimates were based on weighted average fertilizer rates for major crops, emissions factors from Ogle et al. 2010, and the assumption that the woody cover is unfertilized. Ranges for nitrous oxide were based on ranges of average fertilizer rates reported in ARMS (USDA-ERS 2014). | Eve et al. 2014, IPCC 2006, Merwin et al. 2009, Ogle et al. 2010, Paustian et al. 2012 |
| | Moist/ humid | 1.42 (1.06 – 1.89) | 0.28 (0 – 0.50) | Not estimated | | |
| **Alley Cropping (CPS 311)** | Dry/ semiarid | 0.80 (0 – 1.62) | 0.01 (0 – 0.01) | Not estimated | Woody biomass carbon and soil organic carbon estimates were based on a literature review (Nair and Nair 2003). Nitrous oxide estimates were based on weighted average fertilizer rates for major crops (USDA-ERS 2014), emissions factors for North America (Ogle et al. 2010), and the assumption that the woody cover receives 50% less nitrogen fertilizer than annual crops. | Nair and Nair 2003, Ogle et al. 2010, USDA-ERS 2014 |
| | Moist/ humid | 1.71 (0 – 3.43) | 0.03 (0 – 0.05) | Not estimated | | |
| **Multi-story Cropping (CPS 379)** | Dry/ semiarid | 0.80 (0 – 1.62) | 0.01 (0 – 0.01) | Not estimated | No estimates for multi-story cropping were available, so values for alley cropping were used for this practice. See explanation for Alley Cropping for more information. | Nair and Nair 2003, Ogle et al. 2010, USDA-ERS 2014 |
| | Moist/ humid | 1.71 (0 – 3.43) | 0.03 (0 – 0.05) | Not estimated | | |

* Climate designations are based on Intergovernmental Panel on Climate Change climate classifications (IPCC 2006). In dry/semiarid climates, annual potential evapotranspiration exceeds annual precipitation; in moist/humid climates annual precipitation exceeds annual potential evapotranspiration.

| Grazing Lands | | | | | | |
|---|---|---|---|---|---|---|
| **Practice** **(Conservation Practice Standard Number)** | ***Climate zone**** | **Carbon Dioxide** *Average (Range)* | **Nitrous Oxide** *Average (Range)* | **Methane** *Average (Range)* | **Explanation and Notes** | **Primary Sources** |
| | | **Mg $CO_2$ eq acre$^{-1}$ y$^{-1}$** | | | | |
| **Range Planting (CPS 550)** | Dry/ semiarid | 0.34 (0.15 – 0.73) | Not estimated | Not estimated | For the purpose of this tool, it was assumed that grasslands were restored to native conditions or were seeded with improved forages. Limited data was available on the influence of range planting in recent reviews. Emissions reductions were estimated using the IPCC method (IPCC 2006) for grasslands and evaluated as an average of a change from moderately degraded to nominal condition or from nominal to improved condition, with factors from Eve et al. (2014). Reference soil carbon stocks were from Eve et al. (2014) and estimated stock changes were area-weighted using total IPCC soil areas classified from SSURGO soils data, by IPCC climate regions (IPCC 2006, Soil Survey Staff 2011). | Eve et al. 2014, IPCC 2006, Soil Survey Staff 2011 |
| | Moist/ humid | 0.50 (0.30 – 0.78) | Not estimated | Not estimated | | |
| **Silvopasture Establishment on Grazed Grasslands (CPS 381)** | Dry/ semiarid | 0.66 (0.46 – 0.91) | Not estimated | Not estimated | Woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Soil carbon changes were not estimated. No estimates were available for the dry/semiarid climate. Dry/semiarid climate values were estimated as 49% of of the rate for Moist/humid climates. The value of 49% is the average ratio between climates for total carbon changes for windbreaks, riparian buffers and farm woodlots. | Merwin et al. 2009, Paustian et al. 2012 |
| | Moist/ humid | 1.34 (0.94 – 1.86) | Not estimated | Not estimated | | |

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|---|---|---|---|---|---|---|
| **Prescribed Grazing (CPS 528)** | Dry/ semiarid | 0.18 (0.08 – 0.38) | Not estimated | Not estimated | For the purpose of this tool, it was assumed that prescribed grazing was applied to grasslands that were previously degraded due to heavy grazing. Limited data was available on the influence of prescribed grazing in recent reviews. Emissions reductions were estimated using the IPCC method (IPCC 2006) for grasslands and evaluated as a change from moderately degraded to nominal condition, with factors from Eve et al. (2014). Reference soil carbon stocks were from Eve et al. (2014) and estimated stock changes were area-weighted using total IPCC soil areas classified from SSURGO soils data, by IPCC climate regions (IPCC 2006, Soil Survey Staff 2011). | Eve et al. 2014, IPCC 2006, Soil Survey Staff 2011 |
| | Moist/ humid | 0.26 (0.16 – 0.41) | Not estimated | Not estimated | | |

* Climate designations are based on Intergovernmental Panel on Climate Change climate classifications (IPCC 2006). In dry/semiarid climates, annual potential evapotranspiration exceeds annual precipitation; in moist/humid climates annual precipitation exceeds annual potential evapotranspiration.

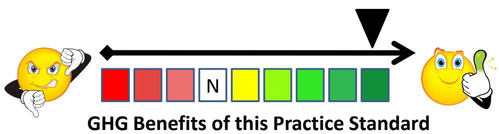
| Restoration of Highly Disturbed Land | | | | | | |
|---|---|---|---|---|---|---|
| **Practice** (Conservation Practice Standard Number) | ***Climate zone**** | **Carbon Dioxide** *Average (Range)* | **Nitrous Oxide** *Average (Range)* | **Methane** *Average (Range)* | **Explanation and Notes** | **Primary Sources** |
| | | **Mg $CO_2$ eq acre$^{-1}$ y$^{-1}$** | | | | |
| **Critical Area Planting (CPS 342)** | Dry/ semiarid | 1.05 (0.68 – 1.40) | Not estimated | Not estimated | For dry/semiarid climates, this practice was assumed to be similar to herbaceous planting, and soil carbon values were from Ogle et al. (2010) for set-aside. In moist/humid climates, woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Soil carbon estimates were derived carbon stock values from Eve at al. (2014) for sandy soils (representing degraded soil) and IPCC 2006 stock change methodology. | Eve et al. 2014, Merwin et al. 2009, Ogle et al. 2010, Paustian et al. 2012 |
| | Moist/ humid | 1.90 (1.02 – 3.65) | Not estimated | Not estimated | | |
| **Land Reclamation – Abandoned Mine Land (CPS 543)** | Dry/ semiarid | 1.05 (0.68 – 1.40) | Not estimated | Not estimated | For dry/semiarid climates, this practice was assumed to be similar to herbaceous planting, and soil carbon values were from Ogle et al. (2010) for set-aside. In moist/humid climates, woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Soil carbon estimates were derived carbon stock values from Eve at al. | Eve et al. 2014, Merwin et al. 2009, Ogle et al. 2010, Paustian et al. 2012 |
| | Moist/ humid | 1.90 (1.02 – 3.65) | Not estimated | Not estimated | | |

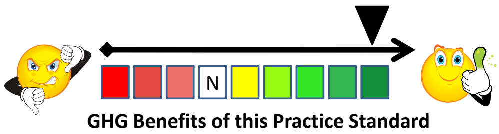
| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | (2014) for sandy soils (representing degraded soil) and IPCC 2006 stock change methodology. | |
| **Land Reclamation – Currently Mined Land (CPS 544)** | Dry/ semiarid | 1.05 (0.68 – 1.40) | Not estimated | Not estimated | For dry/semiarid climates, this practice was assumed to be similar to herbaceous planting, and soil carbon values were from Ogle et al. (2010) for set-aside. . In moist/humid climates, woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Soil carbon estimates were derived carbon stock values from Eve at al. (2014) for sandy soils (representing degraded soil) and IPCC 2006 stock change methodology. | Eve et al. 2014, IPCC 2006, Merwin et al. 2009, Ogle et al. 2010, Paustian et al. 2012 |
| | Moist/ humid | 1.90 (1.02 – 3.65) | Not estimated | Not estimated | | |
| **Land Reclamation – Landslide Treatment (CPS 453)** | Dry/ semiarid | 0.73 (0.47 – 1.09) | Not estimated | Not estimated | For dry/semiarid climates, this practice was assumed to be similar to herbaceous planting, and soil carbon values were from Ogle et al. (2010) for set-aside. . In moist/humid climates, woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Soil organic carbon estimates were derived from carbon stock values from Eve at al. (2014) for sandy soils (representing degraded soil) and IPCC 2006 stock change methodology. | Eve et al. 2014, IPCC 2006, Merwin et al. 2009, Paustian et al. 2012 |
| | Moist/ humid | 1.90 (1.02 – 3.65) | Not estimated | Not estimated | | |

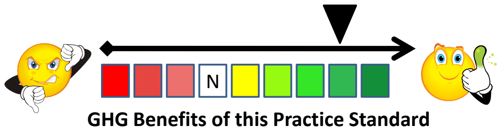
| | | | | | | |
|---|---|---|---|---|---|---|
| **Riparian Restoration (NRCS Program)** | Dry/ semiarid | 1.00 (0.38 – 1.63) | Not estimated | Not estimated | Woody biomass carbon estimates were derived from empirical models of woody biomass carbon accumulation in NRCS agroforestry prescriptions that used tree growth increment data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program and allometric equations to allocate biomass carbon to tree components (Paustian et al. 2012, Merwin et al. 2009). Soil carbon estimates were derived from carbon stock values from Eve at al. 2014 (HAC, LAC, and sandy soils) and IPCC 2006 stock change methodology. | Eve et al. 2014, IPCC 2006, Merwin et al. 2009, Paustian et al. 2012 |
| | Moist/ humid | 2.19 (0.96 – 3.26) | Not estimated | Not estimated | | |

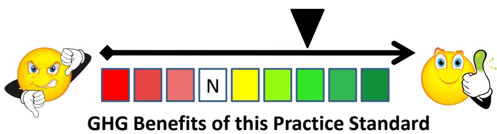
* Climate designations are based on Intergovernmental Panel on Climate Change climate classifications (IPCC 2006). In dry/semiarid climates, annual potential evapotranspiration exceeds annual precipitation; in moist/humid climates annual precipitation exceeds annual potential evapotranspiration.

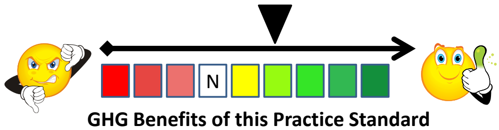
## APPENDIX II: NRCS Practice Standards for Greenhouse Gas Emission Reduction and Carbon Sequestration

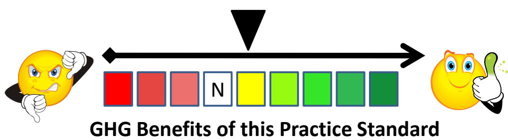
| Qualitative Ranking<br>N=Neutral | Practice Code | Practice Standard and Associated Information Sheet | Beneficial Attributes |
|---|---|---|---|
|  | 327 | Conservation Cover<br>(Information Sheet) | Establishing perennial vegetation on land retired from agriculture production increases soil carbon and increases biomass carbon stocks. |
| | 329 | Residue and Tillage Management, No Till/Strip Till/Direct Seed<br>(Information Sheet) | Limiting soil-disturbing activities improves soil carbon retention and minimizes carbon emissions from soils. |
| | 366 | Anaerobic Digester<br>(Information Sheet) | Biogas capture reduces $CH_4$ emissions to the atmosphere and provides a viable gas stream that is used for electricity generation or as a natural gas energy stream. |
| | 367 | Roofs and Covers | Capture of biogas from waste management facilities reduces $CH_4$ emissions to the atmosphere and captures biogas for energy production. $CH_4$ management reduces direct greenhouse gas emissions. |
| | 372 | Combustion System Improvement | Energy efficiency improvements reduce on-farm fossil fuel consumption and directly reduce $CO_2$ emissions. |
| | 379 | Multi-Story Cropping | Establishing trees and shrubs that are managed as an overstory to crops increases net carbon storage in woody biomass and soils. Harvested biomass can serve as a renewable fuel and feedstock. |
| | 380 | Windbreak/Shelterbelt Establishment<br>(Information Sheet) | Establishing linear plantings of woody plants increases biomass carbon stocks and enhances soil carbon. |
| | 381 | Silvopasture Establishment | Establishment of trees, shrubs, and compatible forages on the same acreage increases biomass carbon stocks and enhances soil carbon. |

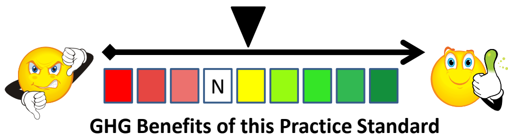
| | | | |
|---|---|---|---|
| Continuation…   | **512** | Forage and Biomass Planting (Information Sheet) | Deep-rooted perennial biomass sequesters carbon and may have slight soil carbon benefits. Harvested biomass can serve as a renewable fuel and feedstock. |
| | **590** | Nutrient Management (Information Sheet) | Precisely managing the amount, source, timing, placement, and form of nutrient and soil amendments to ensure ample nitrogen availability and avoid excess nitrogen application reduces $N_2O$ emissions to the atmosphere. |
| | **592** | Feed Management | Diets and feed management strategies can be prescribed to minimize enteric $CH_4$ emissions from ruminants. |
| | **612** | Tree/Shrub Establishment (Information Sheet) | Establishing trees and shrubs on a site where trees/shrubs were not previously established increases biomass carbon and increases soil carbon. Mature biomass can serve as a renewable fuel and feedstock. |
| | **666** | Forest Stand Improvement (Information Sheet) | Proper forest stand management (density, size class, understory species, etc.) improves forest health and increases carbon sequestration potential of the forest stand. Managed forests sequester carbon above and below ground. Harvested biomass can serve as a renewable fuel and feedstock. |

| Qualitative Ranking<br>N=Neutral | Practice Code | Practice Standard and Associated Information Sheet | Beneficial Attributes |
|---|---|---|---|
|  | 332 | Contour Buffer Strips<br>(Information Sheet) | Permanent herbaceous vegetative cover increases biomass carbon sequestration and increases soil carbon stocks. |
| | 391 | Riparian Forest Buffer<br>(Information Sheet) | Planting trees and shrubs for riparian benefits also increases biomass carbon sequestration and increases soil carbon stocks. |
| | 601 | Vegetative Barrier | Permanent strips of dense vegetation increase biomass carbon sequestration and soil carbon. |
| | 650 | Windbreak/Shelterbelt Renovation<br>(Information Sheet) | Restoring trees and shrubs to reduce plant competition and optimize planting density increases carbon sequestration. |

| Qualitative Ranking<br>N=Neutral | Practice Code | Practice Standard and Associated Information Sheet | Beneficial Attributes |
|---|---|---|---|
|  | 311 | Alley Cropping | Trees and/or shrubs are planted in combination with crops and forages. Increasing biomass density increases carbon sequestration and enhances soil carbon stocks. |
| | 390 | Riparian Herbaceous Cover | Perennial herbaceous riparian cover increases biomass carbon and soil carbon stocks. |
| | 550 | Range Planting<br>(Information Sheet) | Establishing deep-rooted perennial and self-sustaining vegetation such as grasses, forbs, legumes, shrubs and trees improves biomass carbon sequestration and enhances soil carbon. |
| | 603 | Herbaceous Wind Barriers<br>(Information Sheet) | Perennial herbaceous vegetation increases biomass carbon sequestration and soil carbon. |

| Qualitative Ranking<br>N=Neutral | Practice Code | Practice Standard and Associated Information Sheet | Beneficial Attributes |
|---|---|---|---|
|   | **346** | Residue and Tillage Management, Ridge Till<br>(Information Sheet) | Ridge planting promotes organic material accumulation that increases soil carbon. Reconstruction of ridges in the same row year after year will maximize organic matter buildup in the row. Shallow soil disturbance maintains soil carbon in the undisturbed horizons. |
| | **632** | Solid/Liquid Waste Separation Facility | Removal of solids from the liquid waste stream improves the efficiency of anaerobic digesters. $CH_4$ generation is maximized within the digester by separating solids from the liquid feedstock. Proper management of the solid and liquid waste streams increases $CH_4$ that is available for capture and combustion. |

| Qualitative Ranking<br>N=Neutral | Practice Code | Practice Standard and Associated Information Sheet | Beneficial Attributes |
|---|---|---|---|
|   | **342** | Critical Area Planting<br>(Information Sheet) | Establishing permanent vegetation on degraded sites enhances soil carbon and increases carbon sequestration by adding vegetative biomass. |
| | **344** | Residue Management, Seasonal<br>(Information Sheet) | Managing residue enhances soil carbon when crop residues are allowed to decompose on a seasonal basis, increasing soil organic matter and reducing soil disturbance. |
| | **345** | Residue and Tillage Management, Mulch Till<br>(Information Sheet) | Soil carbon increases when crop residues are allowed to decompose, increasing soil organic matter and minimizing soil disturbance. |
| | **384** | Forest Slash Treatment | Woody plant residues managed (chipped, scattered, etc.) on-site will increase soil carbon and soil organic matter. Forest slash that is removed can serve as a renewable fuel and feedstock. |
| | **386** | Field Border<br>(Information Sheet) | Permanent vegetative field borders sequester carbon and increase soil carbon content. |
| | **393** | Filter Strip<br>(Information Sheet) | Herbaceous vegetation in filter strips has slight carbon sequestration benefits and enhances soil carbon. |

| | | | |
|---|---|---|---|
| Continuation…  GHG Benefits of this Practice Standard | **412** | Grassed Waterway (Information Sheet) | Perennial forbs and tall bunch grasses provide slight carbon sequestration benefits, minimize soil disturbance, and increase soil carbon. |
| | **422** | Hedgerow Planting (Information Sheet) | Woody plants and perennial bunch grasses increase biomass carbon stocks and enhance soil carbon. |
| | **543** | Land Reclamation Abandoned Mined Land (Information Sheet) | Establishment of permanent trees, shrubs, and grasses on abandoned and unmanaged lands increases biomass carbon stocks and enhances soil carbon. |
| | **544** | Land Reclamation Currently Mined Land (Information Sheet) | Establishment of permanent trees, shrubs, and grasses increases biomass carbon stocks and enhances soil carbon. Pre-mining baselines are important to establish prior to evaluating any carbon benefits. |
| | **589C** | Cross Wind Trap Strips (Information Sheet) | Perennial vegetative cover increases biomass carbon stocks and enhances soil carbon. Minimized soil disturbance also enhances soil carbon. |
| | **657** | Wetland Restoration (Information Sheet) | Establishment of vegetation, particularly woodland and forest vegetation, increases biomass carbon stocks. Soil organic carbon is increased by incorporating compost as a physical soil amendment. |