Chapter 7
Quantifying Greenhouse Gas Sources and Sinks from Land-Use Change

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Contents:

Suggested Chapter Citation: Ogle, S.M., 2014. Chapter 7: Quantifying Greenhouse Gas Sources and Sinks from Land Use Change. In *Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory.* Technical Bulletin Number 1939. Office of the Chief Economist, U.S. Department of Agriculture, Washington, DC. 606 pages. July 2014. Eve, M., D. Pape, M. Flugge, R. Steele, D. Man, M. Riley-Gilbert, and S. Biggar, Eds.

Acronyms, Chemical Formulae, and Units

C	Carbon
CH_4	Methane
CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide equivalents
DOM	Dead organic matter
EPA	Environmental Protection Agency
FIA	Forest Inventory and Analysis
GHG	Greenhouse gas
ha	Hectare
IPCC	Intergovernmental Panel on Climate Change
N_2O	Nitrous Oxide
NRI	Natural Resources Inventory
PRISM	Parameter-Elevation Regressions on Independent Slopes Model
SOC	Soil organic carbon
SSURGO	Soil Survey Geographic Database
USDA	U.S. Department of Agriculture

7 Quantifying Greenhouse Gas Sources and Sinks from Land-Use Change

This chapter provides guidance on estimating the net greenhouse gas (GHG) flux resulting from changes between land use types—i.e., conversions into and out of cropland, wetland, grazing land, or forestland—at the entity scale. In some cases, it is sufficient to estimate the net GHG flux associated with the new land use. If changing from one land use to another has a significant effect on carbon stocks (e.g., changes in forest carbon stocks, changes in soil carbon), it will be necessary to represent that influence associated with a specific land-use change (e.g., wetland to cropland, grazing land to cropland, forestland to cropland). Table 7-1 provides a summary and description of the sources covered in this chapter.

Table 7-1: Overview of Land-Use Change Sources and Associated GHGs

Source	Method for GHG Estimation			Description
	CO_2	N_2O	CH_4	
Annual change in carbon stocks in dead wood and litter due to land conversion	✓			Live and dead biomass carbon stocks and soil organic carbon constitutes a significant carbon sink in many forest and agricultural lands. Following land-use conversion, the estimation of dead biomass carbon stock changes during transition periods requires that the area subject to land-use change on the entity's operation be tracked for the duration of the 20-year transition period.
Change in soil organic carbon stocks for mineral soils	✓			Soil organic carbon stocks are influenced by land-use change (Aalde et al., 2006) due to changes in productivity that influence carbon inputs, and to changes in soil management that influence carbon outputs (Davidson and Ackerman, 1993; Ogle et al., 2005; Post and Kwon, 2000). The most significant changes in soil organic carbon occur with land-use change, particularly conversions to croplands, due to changes in the disturbance regimes and associated effects on soil aggregate dynamics (Six et al., 2000).

7.1 Overview

In many cases, the methods proposed to estimate contributions to the GHG flux resulting from land-use change are the same as those used to estimate carbon stock changes in the individual chapters on Cropland and Grazing Land, Forestry, and Wetlands; although, in specific cases guidance is also provided on reconciling carbon-stock estimates between discrete data sets and estimation methods (e.g., reconciling forest soil carbon estimates and cropland soil carbon estimates for land-use change from forest land to cropland). Table 7-2 presents the methodologies for each source and indicates their section.

Table 7-2: Overview of Cropland and Grazing Land Systems Sources, Method and Section

Section	Source	Proposed Method
7.4.1	Annual change in carbon stocks in dead wood and litter due to land conversion	The change in carbon stocks in dead wood and litter due to land conversion is estimated as the difference in carbon stocks in the old and new land-use categories applied in the year of the conversion (carbon losses), or distributed uniformly over the length of the transition period (carbon gains) (Aalde et al., 2006).
7.4.2	Change in soil organic carbon stocks for mineral soils	The methodologies to estimate soil carbon stock changes for organic soils and mineral soils are adopted from IPCC (Aalde et al., 2006).

The remainder of this chapter is organized as follows:

- Definitions
- Caveats
- Steps for estimating GHG flux from land-use change
- Overlaps, issues, and assembly instructions for GHG flux estimation from land-use change

7.2 Definitions of Land Use

A land-use categorization system that is consistent and complete (both temporally and spatially) is needed to assess land use and land-use change status within an entity's boundaries. Each entity should ensure that it characterizes all of the land within its boundary according to the following land-use types: cropland, grazing land, forest land, wetland, settlements (e.g., residential, farm, and commercial buildings), and other land (e.g., bare soil, rock). The land-use definitions provided below are expected to be adopted by entities using this report. It is critical that individual parcel areas are estimated accurately and when combined add up to the total land area reported by the entity before and after the land-use change.

Current definitions for land use that are consistent with other policy programs related to GHG estimation (e.g., Intergovernmental Panel on Climate Change (IPCC), Natural Resources Inventory (NRI)) are provided below. These definitions are specific to the United States and are based predominantly on criteria used in the land-use surveys for the United States. Specifically, the definition of forest land is based on the Forest Inventory and Analysis (FIA) definition of forest,[1] while definitions of cropland, grazing land, and settlements are based on the NRI.[2] The definitions for other land and wetlands are based on the IPCC (2006) definitions for these categories.

- *Forest Land*: A land-use category that includes areas at least 36.6 meters wide and 0.4 hectares in size with at least 10 percent cover (or equivalent stocking) by live trees of any size, including land that formerly had such tree cover and that will be naturally or artificially regenerated. Forest land includes transition zones, such as areas between forest and non-forest lands that have at least 10 percent cover (or equivalent stocking) with live trees and forest areas adjacent to urban and built-up lands. Roadside, streamside, and shelterbelt strips of trees must have a crown width of at least 36.6 meters and continuous length of at least 110.6 meters to qualify as forest land. Unimproved roads and trails,

[1] See FIA Glossary http://socrates.lv-hrc.nevada.edu/fia/ab/issues/pending/glossary/Glossary_5_30_06.pdf
[2] See National Resource Inventory Glossary of Selected Terms (p. 9) http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1041379.pdf

streams, and clearings in forest areas are classified as forests if they are less than 36.6 meters wide or 0.4 hectares in size; otherwise they are excluded from forest land and classified as settlements. Tree-covered areas in agricultural production settings, such as fruit orchards, or tree-covered areas in urban settings, such as city parks, are not considered forest land (Smith et al., 2009).

- *Cropland*: A land-use category that includes areas used for the production of adapted crops for harvest; this category includes both cultivated and non-cultivated lands. Cultivated crops include row crops or close grown crops and also hay or pasture in rotation with cultivated crops. Non-cultivated cropland includes continuous hay, perennial crops (e.g., orchards), and horticultural cropland. Cropland also includes land with alley cropping and windbreaks, as well as lands in temporary fallow or enrolled in conservation reserve programs (i.e., set-asides[3]). Roads through cropland, including interstate highways, state highways, other paved roads, gravel roads, dirt roads, and railroads are excluded from cropland area estimates and are, instead, classified as settlements.
- *Grazing Land*:[4] A land-use category under which the plant cover is composed principally of grasses, grass-like plants, forbs, or shrubs suitable for grazing and browsing. This category includes both pastures and native rangelands and areas where practices such as clearing, burning, chaining, and/or chemicals are applied to maintain the grass vegetation. Savannas, some wetlands and deserts, and tundra are considered grazing land. Woody plant communities of low forbs and shrubs, such as mesquite, chaparral, mountain shrub, and pinyon-juniper, are also classified as grazing land if they do not meet the criteria for forest land. Grazing land includes land managed with agroforestry practices such as silvopasture and windbreaks, assuming the stand or woodlot does not meet the criteria for forest land. Roads through grazing land, including interstate highways, state highways, other paved roads, gravel roads, dirt roads, and railroads are excluded from grazing land area estimates and are, instead, classified as Settlements.
- *Wetlands:*[5] A land-use category that includes land with hydric soils, native or adapted hydrophytic vegetation, and a hydrologic regime were the soil is saturated during the growing season in most years. Wetland vegetation types may include marshes, grasslands, or forests. Wetlands may have water levels that are artificially changed, or where the vegetation composition or productivity is manipulated. These lands include undrained forested wetlands, grazed woodlands and grasslands, impoundments managed for wildlife, and lands that are being restored following conversion to a non-wetland condition (typically as a result of agricultural drainage). Provisions for engineered wetlands including

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[3] A set-aside is cropland that has been taken out of active cropping and converted to some type of vegetative cover, including, for example, native grasses or trees.
[4] Note that this definition is the "grassland" definition from the NIR with "grassland" replaced with "grazing land."
[5] The jurisdictional definition of a wetland is "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas" (EPA, 1980). The 1987 Corps of Engineers Wetland Delimitation Manual & Regional Supplements (U.S. Army Corps of Engineers, 1987) is used to identify wetlands in the field.

storm water detention ponds, constructed wetlands for water treatment, and farm ponds or reservoirs are not included. Natural lakes and streams are also not included.

- *Settlements:* A land-use category representing developed areas consisting of units of 0.25 acres (0.1 ha) or more that includes residential, industrial, commercial, and institutional land; construction sites; public administrative sites; railroad yards; cemeteries; airports; golf courses; sanitary landfills; sewage treatment plants; water control structures and spillways; parks within urban and built-up areas; and highways, railroads, and other transportation facilities. Also included are tracts of less than 10 acres (4.05 ha) that may meet the definitions for Forest Land, Cropland, Grassland, or Other Land but are completely surrounded by urban or built-up land, and so are included in the settlement category. Rural transportation corridors located within other land uses (e.g., Forest Land, Cropland, and Grassland) are also included in Settlements.
- *Other Land*: A land-use category that includes bare soil, rock, ice, and all land areas that do not fall into any of the other five land-use categories, which allows the total of identified land areas to match the managed land base.

7.3 Caveats

The methods presented here for quantifying GHG flux from land-use change are intended for use at the entity scale on lands managed to enhance the production of food, feed, fiber, and renewable energy. Methods are currently not provided for estimating emissions from energy used when converting land use from one category to another. Methods are also not provided for land-use change from settlements or the "other land" category to forest land, cropland, grazing land, or wetlands. These methods have been developed for U.S. conditions and are considered applicable to agricultural and forestry production systems in the United States.

7.4 Estimating GHG Flux from Land-Use Change

Method for Estimating GHG Flux from Land-Use Change

- The GHG flux associated with land-use change is estimated based on the balance of carbon losses from the previous land use following conversion and the carbon gains with the current land use.
- This section only covers methodologies for dead organic matter carbon and soil organic matter carbon. Guidance on biomass carbon methods are provided in the land-use-specific sections (Cropland, Grazing land, Forest Land, and Wetlands).
- The change in carbon stocks in dead wood and litter due to land conversion is estimated as the difference in carbon stocks in the old and new land-use categories applied in the year of the conversion (carbon losses), or distributed uniformly over the length of the transition period (carbon gains).
- The methodologies to estimate soil carbon stock changes for organic soils and mineral soils are adopted from IPCC (Aalde et al., 2006).

Rationale for Selected Method

This method is based on the IPCC 2006 Guidelines (IPCC, 2006)and represents the most consistent method for estimating emissions from land-use change. Other methods are provided for land parcels that are not undergoing land use change, and arguably those methods are more comprehensive for estimating emissions for the specific land use. However, it is critical that an individual land parcel has a consistent, seamless method for estimating carbon stock changes throughout the time series. Otherwise artificial changes in stocks can be estimated due to a change in the method. The methods based on the IPCC 2006 Guidelines (IPCC, 2006) provide this consistency and seamless integration. Further testing and development will be needed before the more comprehensive methods provided in each land use section can be integrated into a seamless approach for estimating the carbon stock changes.

Description of Method

For inventory purposes, changes in carbon stock in biomass should be estimated for: (1) land remaining in the same land-use category; and (2) land converted to a new land-use category. The methods provided in this section are strictly for portions of an entity's operation that have undergone a land use change. The soil carbon changes must be addressed over a 20-year period. Aboveground and below ground biomass are estimated on an annual basis. Note that this section only addresses dead organic matter carbon and soil organic matter carbon. Biomass carbon methods should follow the guidance provided in the land-use-specific sections (Cropland, Grazing land, Forest Land, and Wetlands).

The reporting convention is that all carbon stock changes and non-CO_2 GHG emissions associated with a land-use change are reported in the new land-use category. For example, in the case of conversion of forest land to cropland, both the carbon stock changes associated with the clearing of the forest as well as any subsequent carbon stock changes that result from the conversion, are reported under cropland (IPCC, 2006).

The GHG flux associated with land-use change is essentially the sum of the GHG fluxes associated with previous (i.e., old) land-use categories plus the sum of the GHG fluxes associated with the current (i.e., new) land-use categories for a specified area undergoing conversion from the old to new land-use category. GHG emissions and stock changes not resulting from a land-use change are estimated with methods in the land-use-specific sections.

Equation 7-1: Annual Carbon Stock Changes for a Land-Use Change Estimated as the Sum of Changes in All Land-Use Categories

$$\Delta C_{LUC} = \Delta C_{LUC\ o} + \Delta C_{LUC\ n}$$

and

$$\Delta C_{LUC} = \Delta C_{LUC\ FL} + \Delta C_{LUC\ CL} + \Delta C_{LUC\ GL} + \Delta C_{LUC\ WL}$$

Where:

ΔC = carbon stock change (metric tons CO_2-eq ha^{-1} $year^{-1}$)

Indices denote the following land-use categories:

LUC = land-use change
o = old land-use category
n = new land-use category
FL = forest land
CL = cropland
GL = grazing land
WL = wetlands

For each land-use category undergoing a land-use change, it is important to estimate the annual carbon stock change occurring within each stratum or subdivision (e.g., carbon pool, management regime) for that land-use category.

Equation 7-2: Annual Carbon Stock Changes for a Land-Use Change as a Sum of Changes in Each Stratum Within a Land-Use Change

$$\Delta C_{LUC} = \Sigma_i \Delta C_{LUC\ I}$$

Where:

ΔC_{LUC} = carbon stock changes for a land-use change as defined in Equation 7.1 (metric tons CO_2-eq ha^{-1} $year^{-1}$)

i = denotes a specific stratum or subdivision within the land uses undergoing land-use conversion (by any combination of species, climatic zone, ecotype, management regime, etc.), i = 1 to n

For example, in the case of conversion of forest land to cropland, the carbon stock changes associated with each of the forest carbon pools plus harvested wood products should be assessed, as well as any subsequent carbon stock changes that result from the conversion (specific annualized changes in dead organic matter, soil carbon, etc.).

7.4.1 Carbon Pools in Live Biomass, Dead Biomass, and Soil Organic Carbon

Live and dead biomass carbon stocks and soil organic carbon constitute a significant carbon sink in many forest and agricultural lands. Sector-specific methods for estimating changes in biomass carbon stocks are detailed in the individual sector chapters and should be used when estimating the effect of land-use change. In addition to estimating the changes in biomass carbon stocks before and after the land-use change using the sector-specific methods, it is also important to estimate any increase in the harvested wood pool resulting from clearing/harvest of the forest following the methods outlined in Chapter 6, Forestry. Any biomass that is retained on the land during the land-use conversion will need to be included in the estimation, such as conversion of forest to grasslands, where some trees are left to provide shade for grazing livestock.

Following land-use conversion, the estimation of dead biomass carbon stock changes during transition periods requires that the area subject to land-use change on the entity's operation be tracked for the duration of the 20-year transition period. For example, dead organic matter (DOM) stocks are assumed to increase for 20 years after conversion to forest land. After 20 years, the area converted becomes forest and remaining forest land, and no further DOM changes are assumed. The conceptual approach to estimating changes in carbon stocks in dead wood and litter pools is to estimate the difference in carbon stocks in the old and new land-use categories and to apply this change in the year of the conversion (carbon losses), or to distribute it uniformly over the length of the transition period (carbon gains).

7.4.2 Changes in Soil Carbon

Soil organic carbon stocks are influenced by land-use change (Aalde et al., 2006) due to changes in productivity that influence carbon inputs, and to changes in soil management that influence carbon outputs (Davidson and Ackerman, 1993; Ogle et al., 2005; Post and Kwon, 2000). The most significant changes in soil organic carbon occur with land-use change, particularly conversions to croplands, due to changes in the disturbance regimes and associated effects on soil aggregate dynamics (Six et al., 2000). While there is considerable evidence and mechanistic understanding about the influence of land-use change on soil organic carbon, there is less known about the effect on soil inorganic carbon. Consequently, current methods do not include impacts on inorganic carbon uncertainty associated with estimates of land use and management impacts on soil carbon stocks.

Equation 7-3: Annual Change in Carbon Stocks in Dead Wood and Litter Due to Land Conversion

$$\Delta C_{DOM} = (C_n - C_o) \times A_{on} \div T_{on}$$

Where:

ΔC_{DOM} = annual change in carbon stocks in dead wood or litter (metric tons C year^{-1})

C_o = dead wood/litter stock, under the old land-use category (metric tons C ha^{-1})

C_n = dead wood/litter stock, under the new land-use category metric tons C ha^{-1})

A_{on} = area undergoing conversion from old to new land-use category (ha)

T_{on} = time period of the transition from old to new land-use category (year) (The default is 20 years for carbon stock increases and 1 year for carbon losses.)

Estimating changes in GHG emissions, including carbon stocks, require consistency in the methods that are applied across a time series. Applying different methods to account for changes in carbon stocks as the land shifts from one land use to another will lead to artificial changes in the stocks beyond the actual change occurring on the land. Thus, in order to ensure consistency, changes in soil organic carbon stocks will be estimated for the entire time series being reported, using the method described in this section. As noted earlier, estimates should be made separately for each parcel of land that undergoes a change in land use. However, the stock changes will only be reported as a land-use change effect for a 20-year transition period. Applying the same method across the entire time series will limit errors in the estimation of mineral soil organic carbon stock changes that would result from changing methods after the 20-year transition period.

7.4.2.1 Description of Method

Models have been adopted from the IPCC methods to estimate soil organic carbon stock change (Aalde et al., 2006). For mineral soils, the method will require estimates of carbon stocks at the beginning and end of the year in order to estimate the annual change using the equation below. Emissions occur in organic soils following drainage due to the conversion of an anaerobic environment with a high water table to aerobic conditions (Armentano and Menges, 1986), resulting in a significant loss of carbon to the atmosphere (Ogle et al., 2003). Emission estimation methods from organic soils should be consistent with their appropriate sector methodologies (i.e., forestry, croplands, grazing lands, or wetlands).

Mineral Soils: The model to estimate changes in soil organic carbon stocks for mineral soils has been adopted from the method developed by IPCC (Aalde et al., 2006). The change would need to be estimated separately for each area in the entity's operation that is converted from one land use to another. The change in stocks for each area is estimated over five year intervals for the entire reporting time series, using the following equation:

Equation 7-4: Change in Soil Organic Carbon Stocks for Mineral Soils

$$\Delta C_{Mineral} = [(SOC_f - SOC_i) \times CO_2MW] \div D$$

Where:

- $\Delta C_{Mineral}$ = annual change in mineral soil organic carbon stock (metric tons CO_2-eq year^{-1})
- SOC_f = soil organic carbon stock at the end of year 5 (metric tons C)
- SOC_i = soil organic carbon stock at the beginning of year 1 (metric tons C)
- CO_2MW = ratio of molecular weight of CO_2 to C = 44/12 (dimensionless)
- D = time dependence of stock change factors (20 years)

Carbon stocks are estimated using the following equation adapted from the IPCC (Aalde et al., 2006):

Equation 7-5: Soil Organic Carbon Stock for Mineral Soils

$$SOC = SOC_{REF} \times F_{LU} \times F_{MG} \times F_I \times A$$

Where:

- SOC = soil organic carbon stock at the beginning (SOC_i) and end of the five years (SOC_f) (metric tons C)
- SOC_{REF} = reference soil organic carbon stock (metric tons C ha^{-1})
- F_{LU} = stock change factor for land use (dimensionless)
- F_{MG} = stock change factor for management (dimensionless)
- F_I = stock change factor for input (dimensionless)
- A = area of land-use change (ha)

The stock change factors (F_{LU}, F_{MG}, F_I) and reference carbon stocks (SOC_{REF}) are country-specific values developed for the United States (EPA, 2011; Ogle et al., 2003; Ogle et al., 2006). The reference stocks are based on the SOC stocks in croplands (Table 7-3), while the land-use factors represent the relative change in SOC between cropland and grazing lands, forest land, and set-aside cropland (Table 7-4). The management factors represent the influence of tillage in croplands and grassland condition in grazing lands. The input factors represent influences of changing plant productivity on carbon input to soils. Management and input factors are not needed for forest lands (Factors are set to a value of 1).

Organic Soils: The methodology for estimating soil carbon stock changes in organic soils has been adopted from IPCC (Aalde et al., 2006), and is described accordingly in Chapter 4, Wetlands, and Chapter 3, Croplands, and Grazing Lands. Chapter 6, Forestry, recommends soil sampling in cases where there have been significant changes in soil carbon (e.g., land conversion).

Table 7-3: Reference Carbon Stocks (Mg C ha-1) (±1 SE) To Estimate Soil Organic Carbon Stock Changes for Mineral Soils

Soil Type	USDA Taxonomy	Cool Temperate Dry	Cool Temperate Moist	Warm Temperate Dry	Warm Temperate Moist	Sub-Tropical Dry	Sub-Tropical Moist
High activity clay soils	Vertisols, Mollisols, Inceptisols, Aridisols, and high base status Alfisols	42±1.4	65±1.1	37±1.1	51±1.0	42±2.6	57±13.0
Low activity clay soils	Ultisols, Oxisols, acidic Alfisols, and many entisols	45±3.0	52±2.3	25±1.4	40±1.2	39±4.8	47±13.9
Sandy soils	Any soils with greater than 70% sand and less than 8% clay (often Entisols)	24±4.8	40±3.7	16±2.4	30±2.0	33±1.9	50±7.9
Volcanic soils	Andisols	124±11.4	114±16.7	124±11.4	124±11.4	124±11.4	128±15.0
Spodic soils	Spodosols	86±6.5	74±6.8	86±6.5	107±8.3	86±6.5	86±6.5
Wetland soils	Soils with Aquic suborder	86±	89±	48±	51±	63±	48±

Source: EPA (2011) and Ogle et al. (2003) Ogle et al. (2006).

Table 7-4: Carbon Stock Change Factors (±1 SE) to Estimate Soil Organic Carbon Stock Changes for Mineral Soils

Factor	Warm Temperate Moist/Subtropical Moist	Warm Temperate Dry/Subtropical Dry	Cool Temperate Moist	Cool Temperate Dry
Land-Use Factor				
Long-term cultivated	1	1	1	1
Forest/grassland	1.42±0.06	1.37±0.05	1.24±0.06	1.20±0.06
Set-aside	1.31±0.06	1.26±0.04	1.14±0.06	1.10±0.05
Cropland Management				
Full till	1	1	1	1
Reduced till	1.08±0.03	1.01±0.03	1.08±0.03	1.01±0.03
No-till	1.13±0.02	1.05±0.03	1.13±0.02	1.05±0.03
Grassland Management[a]				

Factor	Warm Temperate Moist/Subtropical Moist	Warm Temperate Dry/Subtropical Dry	Cool Temperate Moist	Cool Temperate Dry
Non-degraded	1	1	1	1
Moderately degraded	0.95±0.06	0.95±0.06	0.95±0.06	0.95±0.06
Severely degraded	0.7±0.14	0.7±0.14	0.7±0.14	0.7±0.14
Improved	1.14±0.06	1.14±0.06	1.14±0.06	1.14±0.06
Cropland input				
Low	0.94±0.01	0.94±0.01	0.94±0.01	0.94±0.01
Medium	1	1	1	1
High	1.07±0.02	1.07±0.02	1.07±0.02	1.07±0.02
High with amendment[a]	1.38±0.06	1.34±0.08	1.38±0.06	1.34±0.08
Grassland input[a]				
Medium	1	1	1	1
High	1.11±0.04	1.11±0.04	1.11±0.04	1.11±0.04

[a] Grassland management and input factors are from the 2006 IPCC Guidelines (Verchot et al., 2006) as well as the high input systems with manure in croplands (Lasco et al., 2006).

7.4.2.2 Activity Data

Mineral soils require the following activity for croplands:

- Crop selection and rotation sequence;
- Residue management, including harvested, burned, grazed, or left in the field;
- Irrigation, yes or no;
- Mineral fertilization, yes or no;
- Lime amendments, yes or no;
- Organic amendments, yes or no;
- Tillage implements, which can be used to determine tillage classification (i.e., full tillage, reduced tillage, and no-till); and
- Cover crops, yes or no.

The method for grazing land requires the following management activity data:

- Degradation status, non-degraded, moderately degraded, severely degraded;
- Irrigation, yes or no;
- Mineral fertilization, yes or no;
- Seeding legumes, yes or no;
- Lime amendments, yes or no; and
- Organic amendments, yes or no.

The method for forest land does not require any management activity data because the method provided here assumes limited influence on soil organic carbon stock changes associated with forest management after a land-use change (i.e., the land-use change has the largest impact).

The activity data are used to classify land-use, management, and input classes. The classifications can be found in Lasco et al. (2006) for cropland (Figure 5.1), and Verchot et al. (2006) for grassland (Figure 6.1).

7.4.2.3 Ancillary Data

Ancillary data include climate regions and soil types, consistent with the method developed by the IPCC (Bickel et al., 2006). Weather data may be based on national datasets such as the Parameter-Elevation Regressions on Independent Slopes Model (PRISM) data (Daly et al., 2008) and are classified according to the IPCC classification as refined for the United States (Table 7-5). Soils data may also be based on national datasets such as the Soil Survey Geographic Database (SSURGO) (Soil Survey Staff, 2011), and are classified according to the IPCC classification (Bickel et al., 2006; Figure 3A.5.3). However, entities may also substitute field-specific soils data, as long as entities characterize the soil pedons necessary for use of the IPCC classifications. These characteristics include sand and clay content, soil order, and suborder (See Table 7-3).

Table 7-5: Climate Classification for the Soil Organic Carbon Methods Associated with Land-Use Change

Climate Type	Mean Annual Temperature (°C)	Mean Annual Precipitation (mm)
Cool temperate dry	<10	<Potential evapotranspiration
Cool temperate moist	<10	≥Potential evapotranspiration
Warm temperate dry	10-20	<Potential evapotranspiration
Warm temperate moist	10-20	≥Potential evapotranspiration
Subtropical dry	>20	<1000
Subtropical moist	>20	1000-2000

Source: Bickel et al. (2006).

7.4.2.4 Model Output

Model output is generated as an absolute quantity of emissions. The change in mineral soil organic carbon stocks is estimated based on stock changes over five-year time periods (Equation 7.4). In addition, trends in soil organic carbon will be estimated for the entire time series associated with the parcel of land, including 20 previous years of history, in order to present the longer term trends and provide an adequate baseline of data and consistency in the time series for reporting purposes.

7.4.2.5 Limitations and Uncertainty

The limitations of the mineral soil organic carbon method include no assessment of the effect of land-use change at deeper depths in the profile (IPCC method only addresses changes in top 30 cm of soil profile; Aalde et al., 2006), and no assessment of erosion, transport, and deposition of carbon. Uncertainties in the mineral soil methods include imprecision in the emission factors, in addition to uncertainties in the activity and ancillary data. Uncertainty in the emission factors is provided in this guidance (Ogle et al., 2003; Ogle et al., 2006). Uncertainty in the activity data is based on the entity input, as well as the ancillary data to the extent that this information is provided by the entity. Uncertainties can be combined using a Monte Carlo simulation approach.

7.4.3 Changes in other GHG emissions

As previously mentioned, changes in other GHG emissions—i.e., non-CO_2 emissions— associated with a land-use change should be included in any estimation of the GHG flux strata associated with the outgoing or incoming land-use change. While changes in biomass and soil carbon stocks are likely to dominate the GHG flux, there are a number of activities that may occur during land-use conversion that might result in non-CO_2 emission. For example, if forest harvest residues (and other dead organic matter) are piled and burnt as part of the conversion of forest land to another land use, in addition to the change in carbon stock the residue burning will result in emissions of N_2O and CH_4; and if wetlands are cleared and drained prior to conversion to another land use (e.g., grazing lands, peat extraction), in addition to the change in carbon stock from clearing, the draining will result in a reduction in emissions of CH_4, and a possible increase in emissions of N_2O, depending on the nitrogen content of the wetland soil (i.e., peat).

Sector-specific methods for estimating changes in biomass burning non-CO_2 emissions (e.g., for cropland and grazing land systems) and soil non-CO_2 emissions (e.g., for wetland systems) are detailed in the individual sector chapters.

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