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Methodology for Compost Additions to Grazed Grasslands

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A. Methodology Description

A.1 Acronyms

ACR	American Carbon Registry
CDM	Clean Development Mechanism
CH_4	Methane
CO_2	Carbon Dioxide
EPA	Environmental Protection Agency
ERT	Emission Reduction Ton
GHG	Greenhouse Gas
N_2O	Nitrous Oxide
NRCS	Natural Resources Conservation Service
PBM	Process-based Biogeochemical Model
SOC	Soil Organic Carbon
VCS	Verified Carbon Standard
VVB	Validation and Verification Body

A.2 Background

Grazed grasslands are defined by the Natural Resource Conservation Service (NRCS) of the United States Department of Agriculture (USDA) as "land on which the vegetation is dominated by grasses, grass-like plants, shrubs and forbs." This definition includes land that contains forbs, shrubland, improved pastureland, and improved rangeland for which grazing is the predominant use (NRCS 2009). Adding compost to Grazed Grasslands can be an effective way to increase soil carbon sequestration and avoid emissions related to the anaerobic decomposition of organic waste material in landfills. In addition to climate benefits, adding compost stimulates forage growth and can improve the quality of soils. This document contains a methodology to account for the carbon sequestration and avoided GHG emissions related to compost additions to Grazed Grasslands, following specifications by the American Carbon Registry (ACR). The current version of this methodology includes only one project activity – compost addition to Grazed Grasslands. Additional project practices and additional organic soil amendment types may be added in future revisions. This approach will allow the experience gained from the first projects to be incorporated in future versions of the methodology.

Grassland soils are an important sink for carbon, accounting for approximately 20 % of the world's soil carbon stocks (FAOSTAT 2009; Conant 2010). The amount of carbon stored in grassland soils is largely driven by environmental conditions such as temperature, rainfall, and soil characteristics, as well as the productivity of various grassland plant communities (Derner and Schuman 2007). These factors are subject to temporal variability both within seasons and across multiple years (Svejcar et al. 2008; Ingrahm et al. 2008). Many grasslands in the US have been degraded through overgrazing which in some cases can lead to declines in soil organic matter (Conant and Paustian 2002). However, research also suggests that with improved management grassland soils can also offer considerable potential to aid greenhouse mitigation efforts through additional soil carbon sequestration (Lal 2002; Conant and Paustian 2002; Derner and Schuman 2007).

One management strategy that may hold promise for enhancing carbon sequestration in grasslands is the application of organic soil amendments such as compost or composted biosolids. A growing body of research indicates that the application of these organic materials can often have positive impacts on the amount of carbon stored in both grassland (Walter et al. 2006; Ippolito et al. 2010; Kowaljow et al. 2010; Ryals et al. 2014) and cropland soils (Canali et al. 2004; Celic et al. 2004; Montovi et al. 2005; Cai and Qin 2006). The buildup of soil carbon occurs via two mechanisms; 1) directly from carbon contained in the compost, and 2) indirectly through enhanced plant growth and subsequent deposition of plant biomass (Walton et al. 2001; Walter et al. 2006; Ryals and Silver 2013). The recent model work of Zhai et al. 2014 demonstrates gains in soil organic carbon due to application of biosolids for 10 years, with further SOC gains over the next 10 or more years due to biomass and/or carbon sequestration.

A number of peer-reviewed studies involving the application of compost or composted biosolids to temperate grasslands have been carried out over both short-term (0-5 yrs) and long-term (5-14 yrs) experimental periods. At two Mediterranean grassland sites in California, Ryals et al. (2014) measured C sequestration years after a single compost addition. Compost amendment resulted in a significant increase in bulk soil organic C content at a Central Valley site, and a similar but non-significant trend at a Coast Range site. Compost additions also significantly increased plant growth as measured by net primary productivity at both the Central Valley and Coast Range sites (Ryals and Silver 2013). Likewise, in a three year study conducted at a semi-arid steppe site in northwest Patagonia, the application of composted biosolids (40 t ha-1) also increased plant growth and soil organic matter relative to an untreated control (Kowaljow et al. 2010). More importantly, several long-term grassland experiments have also found that the effect of compost application on plant growth and soil C can persist for more than a decade (Sullivan et al. 2006; Ippolito et al. 2010; Walton et al. 2001). For instance, at a semi-arid grassland site in Colorado differences in plant growth (Sullivan et al. 2006) and total soil C (Ippolito et al. 2010) were still detectable 14 years after applying compost at 6 different rates (0, 2.5, 5, 10, 21, and 30 t ha-1). Similarly Walton et al. (2001) found that 32% of applied biosolids remained as particles greater than 2mm 18 years after application to an arid rangeland site in New Mexico. The above-mentioned studies and others in the broader peer-reviewed literature provide evidence that compost application to grasslands can facilitate long-term soil C sequestration and improved plant growth, and thus form the scientific basis for the current methodology.

A.3 Summary Description of the Methodology

Compost additions to Grazed Grasslands can generate Emission Reduction Tons (ERTs) from avoided Greenhouse Gas (GHG) emissions and removals resulting from three processes:

1) **Avoidance of anaerobic decomposition (Optional)** of the organic material used in compost production. Methane (CH_4) emissions that result from anaerobic decomposition of the organic material used in the production of compost under baseline conditions – for example, when the organic matter is buried in landfills – can be avoided by composting[1] and applying compost on Grazed Grasslands. It is not required in this methodology to include the avoided emissions from preventing the anaerobic decomposition of the organic material used in the production of compost. However, if these avoided emissions are included, evidence must be provided that (1) the avoided emissions have not been claimed under a different Carbon Credit program, such as the Climate Action Reserve's composting methodology, and that (2) the baseline fate of the organic matter can be demonstrated following the procedures included in Section C of this methodology.
2) **Direct increase in soil organic carbon (SOC) content (Required)** through adding a carbon source from compost. The carbon (C) content of applied compost will lead to a direct increase in soil organic carbon (SOC) content of the Grazed Grasslands where the compost is applied. Even though the carbon added through compost additions will gradually decompose over time, a significant portion will end up in stable carbon pools. The portion of the compost carbon that will remain in the stable pools is likely to be greater than the portion that would be stabilized under baseline conditions. Only the stable carbon pools that are predicted to remain after 40 years after compost addition can be counted. These stable soil C pools are conceptually equivalent to the "intermediate" and "passive" C pools defined in recent literature reviews by Trumbore (1997) and Adams *et al.* (2011). This 40 year period is also similar in duration to the 40 year minimum project term used in the approved ACR Forest Carbon Project protocol (ACR 2010). As such, the minimum project period for this protocol is 40 years.
3) **Indirect increase in SOC sequestration (Required)** through enhanced plant growth in Grazed Grasslands amended with compost. The N and P content of the compost, as well as the improved soil water holding capacity of soils amended with compost, may in some cases lead to an indirect increase in SOC content through an increase in net primary productivity (NPP). The impact of compost on SOC content will depend on the compost's nutrient content and availability, the soil properties, and grazing management strategies.

This methodology requires the use of a model to predict direct and indirect changes in SOC under the baseline and project scenarios. This methodology does not prescribe a specific model. The model can be either a process-based biogeochemical model (PBM) such as the DAYCENT or Denitrification-Decomposition (DNDC) models, or an empirical model such as a Tier-2 Empirical Model that is shown to

[1] Whereas composting is mostly an aerobic process that occurs in presence of oxygen, composting may still release a small amount of methane.

be effective for the conditions of the Project Parcels (see Section D.1). It is up to the project proponents to demonstrate that the model is sufficiently accurate for the Project Parcels (see section D.1 for model requirements). Under the baseline scenario, the model is used to simulate any on-going changes to SOC, including potential continuing loss of SOC. Under the project scenario, the model is used to simulate the amount of compost carbon that is stored in recalcitrant SOC pools, and any indirect changes in SOC due to an increase in net primary production and under specific grazing management strategies. Even though empirical models and PBMs have been shown to be highly valid across a wide range of management practices and geographic areas, soil samples and field measurements are required to validate the models for use in specific Project Parcels. As a consequence, this methodology requires monitoring by periodic (10 year) analyses of soil samples for model validation at different times throughout the project's lifetime.

Adding compost to Grazed Grasslands has the potential to increase GHG emissions from secondary sources. Specifically, N_2O emissions from soils are produced due to nitrification and de-nitrification of the available N added through the compost addition (Box 1). These processes further require a carbon source, which is readily available after compost addition. Indirect emissions from nitrate leaching may also occur but GHG emissions resulting from the leached nitrate are expected to be insignificant, at the rate compost is applied in projects under this methodology based on findings reported by DeLonge et al. (2013) for California grasslands. In addition to soil N_2O emissions (from de-nitrification), all emissions from fuel that was used to create, transport, or apply the compost is included in the quantification procedure. Under this methodology, soil N_2O emissions are quantified using an applicable Tier-2 Empirical Model, or a calibrated PBM. The GHG emissions from increased fuel use must be quantified using standard emission factors. Likewise, enteric emissions from increases in stocking must be quantified with the ACR Grazing Land and Livestock Management MICROSCALE Tool for Tier I estimation of emissions from enteric methane.

Apart from the economic benefit of increased forage production, applying compost to Grazed Grasslands also has many environmental co-benefits, such as improved soil quality and increased nutrient and water availability for vegetation due to improved soil water holding capacity, which increases resilience to more intense precipitation events, slows the onset of drought, and confers additional ecosystem services. Compost application may also reduce erosion in certain contexts due to improvements in vegetation cover. Compost can be added to most existing Grazed Grasslands.

Box 1. Further background on N_2O fluxes after compost application

The magnitude of the N_2O fluxes after compost addition may be highly variable and difficult to predict. For example, in an experiment where N_2O fluxes were measured after a one-time compost addition on two sites in California, no significant increases in N_2O fluxes were observed (Ryals and Silver 2012). In laboratory incubations under controlled conditions, however, a pulse of N_2O emissions was detected in soils after compost addition that was significantly greater than soils to which no compost was added. However, the pulse was short-lived (four days), and represented only a very small component of the net soil GHG emissions (expressed as CO_2-equivalents) released from the controlled wet up event (Ryals and

Silver 2012). Such conditions represent ideal conditions for N_2O release and are unlikely to be present for a long period of time in the field. High-nitrogen organic materials such as manure or processed manure additions may be more prone to N_2O emissions. Due to the difficulty in predicting N_2O emissions, this methodology allows some flexibility in the approach to quantify N_2O.

Production of N_2O is generally greatest under warm and humid conditions and where soil nitrogen concentrations are highest. Therefore, the timing of compost application relative to weather conditions and plant demand is crucial to minimize N_2O emissions. If the Grazed Grassland is dominated by annual plants and the compost application occurs before plant establishment, a significant amount of inorganic N may remain in the soil, resulting in significant N_2O fluxes. However, in a Mediterranean climate, there is an ideal window for applying compost. Specifically, fall applications are preferred, ideally shortly before first rains and prior to plant establishment in annual-dominated grasslands. Once the soil gets wet, compost applications may become more logistically challenging due to restricted access to the field as well as less beneficial, while initial growth of annuals in response to early rains can be expected to help limit inorganic N losses from the soil. The ideal window for compost addition may be different for other climates. In this protocol we require following the advice from a Qualified Expert (i.e., a Certified Rangeland Manager, NRCS Soil Conservationist or Qualified Extension Agent) as to when to apply compost.

A.4 Definitions

If not explicitly defined here, the current definitions in the latest version of the American Carbon Registry Standard apply.

Compost	The end product of a process of controlled aerobic decomposition of organic materials, consistent with California Department of Resources Recycling and Recovery (CalRecycle) standards (http://www.calrecycle.ca.gov/Laws/Regulations/Title14/ch31.htm).
Grassland	We follow the terminology of Allen et al. (2011), who indicate that the term grassland bridges pastureland and rangeland and may be either a natural or an imposed ecosystem. Grassland has evolved to imply a broad interpretation for lands committed to a forage use.
Grazed Grassland	Grassland on which annual grazing by livestock (including cattle, horses, sheep and goats) is the primary means of forage/biomass removal. In this protocol, if any grazing takes place on a yearly basis under historical baseline management the parcel may be considered “grazed” (see section E.1).
Native Grassland	A grassland where native plant species comprise greater than 10 percent of the

	total relative cover (Stromberg et al. 2007).
Process-based Biogeochemical Model	Computer model that is able to simulate biogeochemical processes and predict GHG fluxes, nutrient contents and/or water contents.
Project	The activities undertaken on a Project Parcel to generate GHG emission reductions.
Project Parcel	Individual contiguous parcel unit of grassland under control of the same entity/entities.
Qualified Expert	A Qualified Expert can be a Certified Rangeland Manager, NRCS Soil Conservationist or Qualified Extension Agent. A Qualified Expert is a professional certified to provide consulting services on all activities devoted to rangeland resources. These services include, but are not limited to, making management recommendations, developing conservation plans and management plans, monitoring, and other activities associated with professional rangeland management.
Stocking Rate	The amount of land allocated to each livestock unit for the grazing period of each year, or alternatively, the number of livestock units per hectare for the grazing period. Stocking Rate must include the number of livestock units (LU)[2], land area per LU, and the amount of time a given number of LUs occupy a given unit of land. In case rotational grazing is employed, the Stocking Rate shall include specifics on the rotational grazing management, including such factors as species, numbers, length of stay, length of rest between grazing periods, frequency of return per annum or season, season(s) of use, etc.
Tier-2 Empirical Model	Empirical model such as a linear regression model calibrated for a specific region. In the context of this methodology, a Tier-2 Empirical Model predicts SOC content or N_2O emissions as a function of one or more driving variables, such as compost carbon added, nitrogen added, clay content, annual rainfall, etc.
Waste Material	The original material that was Composted.

[2] Livestock units (also known as animal units) are a standardized measure used by the UN Food and Agriculture Organization to quantify Stocking Rates for multiple animal types and growth stages based on an estimate of the metabolic weight of the animals. A livestock unit is measured as livestock unit/time/hectare. More information on the quantification of livestock units for grazing systems in North America can be found at: http://www.lrrd.org/lrrd18/8/chil18117.htm

A.5 Applicability Conditions

In addition to satisfying the latest ACR program requirements, project activities must satisfy the following conditions for this methodology to apply:

- The Project includes one or more Project Parcels that are Grazed Grasslands at the start of the Project and remain Grazed Grasslands for the duration of the Project (Box 2).
- The annual, minimum and maximum Stocking Rate shall be determined via consultation with a Qualified Expert (see definitions – a Certified Rangeland Manager, NRCS Soil Conservationist or Qualified Extension Agent) and duly justified by the Project Proponent. Justification for the annual Stocking Rate should include a calculation of the historical Stocking Rate averaged over a 5 year period prior to the start of the Project, and an assessment of whether or not the forage productivity and quality of the parcel can sustainably support the historical Stocking Rate. In some cases the conditions of the parcel will justify using the historical Stocking Rate as the annual, while in other cases the Qualified Expert may set an annual Stocking Rate that differs from the historical Stocking Rate. Validation of the GHG project plan will include a review of the criteria used by the Qualified Expert to ensure annual Stocking Rates during the Project lifetime are sustainable, and will not lead to erosion or negatively affect species composition; subsequent verifications will review changes to the annual Stocking Rate and ensure that a Qualified Expert was properly consulted. The maximum Stocking Rate shall be set so that rangeland utilization remains sustainable, taking into account an increase in forage production and any changes in the percentage of grazer feed coming from purchased sources after the start of the crediting period.[3] The minimum Stocking Rate shall be set to ensure that plant community species composition does not change toward a less desirable plant community in response to soil quality changes following compost application.
- Any soils that are regularly flooded (i.e. more than two months per year), shall be excluded from the Project Parcels.[4] At the start of the Project the Qualified Expert must identify any land within the parcel that ought to be excluded due to a high likelihood of annual flooding. These areas can be detected by observing the topographic position in the landscape, as well as clear shifts in vegetation and soil redox features (e.g. gleying). These areas must be excluded from the Project Parcel at the beginning of the crediting period. Additionally, and in consultation with a Qualified Expert, compost application should occur in accordance with local and/or state regulations regarding application and water quality concerns. In order to prevent any unintended negative impact on forage growth, compost should not be more than ½ inch in depth at any part of the application area.
- The compost added to the Project Parcel must be within the following specifications:

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[3] This approach is fully compatible with a rotational grazing strategy.

[4] The no-flood requirement is added to prevent the inclusion of land areas where a significant amount of CH_4 is likely to be emitted from soils in the project area; the accounting for methanogenesis is not included.

- The final end product after composting must have a nitrogen concentration of less than 3%[5] on a dry-weight basis.
- Best Management Practices put forward by state agencies have been followed in making the compost free of any seeds or propagules capable of germination or growth.
- The heavy metal and contaminant content of composts shall not exceed limits of the US EPA under 40 CFR 503.[6]
- The compost must be produced in accordance with Chapter 5 of EPA Part 503 Biosolids Rule process to further reduce pathogens (PFRP) and other contaminants.[7]
- Waste Material containing food waste or manure must be either (1) mixed and incorporated into the composting process within 24 hours of delivery of the waste to the composting facility, (2) covered or blended with a layer of high-carbon materials such as wood chips or finished compost within 24 hours of delivery, and mixed and incorporated into the composting process no more than 72 hours after delivery, (3) placed in a controlled environment within 24 hours of delivery, or (4) handled using any other alternative Best Management Practices to avoid anaerobic decomposition after delivery and before incorporation into the composting process of the source material.[8] Compost material that was produced consistently with the standards put forward by the California Department of Resources Recycling and Recovery is automatically approved.

Box 2. Further background on species composition changes and minimum grazing requirements

Compost applications may lead to changes in the plant community (either positive or negative) due to impacts of compost on nutrient concentrations and hydrology of treated soils (Bremer, 2009). The protocol does not support application of compost to intact, healthy native plant communities. Whether a grassland constitutes a healthy native plant community is best determined in consultation with a

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[5] This would prevent materials that more closely resemble synthetic fertilizers from being used as an amendment.

[6] Because compost may contain trace levels of heavy metals, limits on the heavy metal contents in fertilizers, organic amendments, and biosolids are regulated through US EPA, 40 CFR Part 503. Under EPA regulations, managers must maintain records on the cumulative loading of trace elements only when bulk biosolids do not meet EPA Exceptional Quality Standards for trace elements.

[7] Chapter 5 focuses on Pathogen and Vector Attraction Reduction Requirements. On page 116, the Process to Further Reduce Pathogens is defined as "*using either the within-vessel composting method or the static aerated pile composting method, the temperature of the biosolids is maintained at 55/degree C or higher for 3 days. Using the windrow composting method, the temperature of the biosolids is maintained at 55/degree C for 15 days or longer. During the period when the compost is maintained at 55/degree C or higher, the windrow is turned a minimum of five times.*". The text is available at http://water.epa.gov/scitech/wastetech/biosolids/upload/2002_06_28_mtb_biosolids_503pe_503pe_5.pdf

[8] These requirements will ensure that emissions from storing waste at the composting facility are negligible, as justified in the "Organic Waste Composting Project Protocol" approved for use under the Climate Action Reserve.

qualified expert, as native plant communities are defined by their geography and are thus impacted by local conditions. Species composition may also change where grazing is discontinued due to factors unrelated to the project activity, such as extended periods of drought.[9] To reduce this risk, validation of the GHG project plan will include a review of the criteria used by the Qualified Expert to ensure that annual Project Stocking Rates will not contribute to erosion or otherwise negatively impact plant species composition. Changes to the annual Stocking Rate will be assessed during each subsequent verification to ensure changes were implemented in consultation with a Qualified Expert. The minimum Stocking Rate shall be set to ensure that plant community species composition is not negatively affected in response to soil quality improvement following compost application.

[9] Guidance on best practices for drought management can be found online at: http://pss.okstate.edu/publications/publications-master-list/copy_of_publications/forages/F-2870web.pdf

B. Project Boundaries

B.1 Geographic Boundary

B.1.1 Project Parcel

The GHG removals from carbon sequestration in the soil organic carbon pools of the Project Parcels are the focus of this methodology. The geographical boundary encompassing these Project Parcels is, therefore, the main geographic boundary of the Project. The geographical coordinates of the boundaries of each Project Parcel must be unambiguously defined by providing geographic coordinates.

New Project Parcels may be added to an existing Project after the start of the crediting period as long as all the applicability criteria are met for each individual Project Parcel, as outlined in ACR's most recent Standard.

B.1.2 Composting Facility (Optional)

In case GHG emission reductions from composting source material and avoidance of anaerobic decomposition are claimed as Emission Reduction Tons (ERTs) under this methodology, the composting facility shall be included in the geographic boundary. In this case, the project proponent(s) shall include a formal affidavit indicating that the emission reductions from composting source material and avoidance of anaerobic decomposition have never been claimed under any compliance or voluntary carbon registry. This affidavit would be issued by the project proponent(s) but will also include a signature from the owner of the composting facility attesting that the facility is not claiming carbon credits.

In case emission reductions from composting source materials are not claimed by the project participants, the composting facility is excluded from the Project's Geographic Boundary.

B.1.3 Stratification

This methodology encourages combining Project Parcels spread over a large geographic region within one Project to reduce costs. However, environmental, soil, and management conditions may not be homogeneous across a large geographic region. Non-homogeneous conditions may affect the validity of baseline calculations and additionality checks. Therefore, heterogeneous Project Parcels shall be subdivided into smaller units or strata that are considered homogeneous for the purpose of carbon accounting. A different set of input parameters to the model(s) for carbon accounting selected in Section D.1 shall be prepared for each different stratum. Parameters that shall be considered to stratify the Project Parcels are:

- Historical rangeland management practices
- Future rangeland management practices after the start of the Project

- Different soil types, especially special status soils (e.g., serpentine soils, histosols, etc.); official soil series description
- Ecological characteristics (soil texture, aspect, slope, hydrology, climate, plant communities)
- Degradation status (initial soil C content, soil bulk density)
- Differences in legally binding requirements affecting management of the Project (e.g., easement status of land, ownership)

The stratification must be conducted or approved by a Qualified Expert. A description and justification of the stratification procedure must be included in the GHG Project Plan. All subsequent procedures in this methodology, including baseline scenario identification and additionality tests must treat each identified stratum separately.

B.2 Greenhouse Gas Boundary

This section includes all sources, sinks, and reservoirs that are quantified in this methodology.

Baseline scenario:

- Emissions resulting from anaerobic decay of organic waste at a final disposal/treatment system (e.g., landfill or manure management system). This source is optional and may be omitted; doing so is conservative. If the composting facility will claim emission reductions from avoiding emissions from anaerobic decay of organic waste, this source may not be included in the GHG accounting for the project. If this source of emission reductions is claimed by the Project, the project proponent(s) shall include a formal affidavit indicating that no other party than the project proponent(s) have claimed the emission reductions from composting source material and avoidance of anaerobic decomposition under any compliance or voluntary carbon registry.
- Background changes of SOC, potentially related to continuous loss of soil organic carbon[10] of the Grassland as predicted through modeling.
- Enteric fermentation CH_4 emissions from ruminants grazing on project parcels.

Project scenario:

- Emissions resulting from the composting process, including active composting and curing of compost at project facilities. To avoid double deductions, this source of emissions shall be omitted in case the composting facility claims emission reductions for avoiding emissions from anaerobic decay of organic waste.
- Enteric fermentation CH_4 emissions from ruminants grazing on project parcels.
- Fossil fuel emissions from the transport of the finished compost to the Project Parcels.
- Emissions related to the land application of compost.

[10] Some evidence indicates that many grasslands are losing soil carbon (Chou *et al*. 2008, Ryals et al. submitted). Through compost additions, one may be able to slow down or reverse the carbon loss (Ryals & Silver 2013).

- Emissions of CO_2 and N_2O related to the decomposition of compost after application.
- Sequestration of carbon related to the increase in plant productivity on the grassland.
- Sequestration related to the transfer of compost into recalcitrant SOC pools.[11]

Fossil fuel emissions from transport of organic waste materials to final disposal/treatment system (e.g. garbage trucks, hauling trucks, etc.) under baseline conditions are assumed to be equal to the fossil fuel emissions from transporting waste materials to the compost facility in the project case[12], and are therefore not included in the GHG accounting (Brown et al. 2009).

The GHG emissions from storage of waste in the composting facility are assumed to be insignificant when the applicability conditions laid out in Section A.5 are followed.

[11] Only carbon stored in recalcitrant soil pools is considered sequestered

[12] Note that in case of on-farm composting, the fossil fuel emissions will likely be smaller in the project scenario. However, it is conservative to omit this extra emission reduction in case of on-farm composting.

Table 1. Overview of included Greenhouse Gas sources.

	Source	Gas	Included?	Justification/Explanation
Baseline	Project Parcels soil	CO_2	Yes	Emissions from decomposition of soil organic carbon
		CH_4	No	Non-flooded soils can be a source or sink of Methane but fluxes are negligible.
		N_2O	Yes	Nitrous oxide emissions from non-fertilized grassland soils are small but not negligible.
	Landfill or other waste sink	CO_2	Yes/No	Carbon dioxide emissions from organic materials are potentially significant in case these materials would have been deposited in landfills. This emission source is optional; omitting this source of emissions is conservative. However, when the composting facility claims emission reductions for avoiding emissions from anaerobic decay of organic waste, this source of emissions shall be omitted to avoid double deductions. This source must also be omitted in cases where the project developer does not know which landfill or other waste sink the material would have gone in the baseline scenario.
		CH_4	Yes/No	Methane emissions from organic materials are potentially significant in case these materials would have been deposited in landfills. This emission source is optional; omitting this source of emissions is conservative. However, when the composting facility claims emission reductions for avoiding emissions from anaerobic decay of organic waste, this source of emissions shall be omitted to avoid double deductions. This source must also be omitted in cases where the project developer does not know which landfill or other waste sink the material would have gone in the baseline scenario.
		N_2O	Yes/No	Nitrous oxide emissions from organic materials are potentially significant in case these materials would have been deposited in

				landfills. This emission source is optional; omitting this source of emissions is conservative. However, when the composting facility claims emission reductions for avoiding emissions from anaerobic decay of organic waste, this source of emissions shall be omitted to avoid double deductions. This source must also be omitted in cases where the project developer does not know which landfill or other waste sink the material would have gone.
	Ruminants	CH_4	Yes	Methane emissions from enteric fermentation from ruminants grazing on the land.
	Fossil fuel emissions from transport of organic waste to landfill	CO_2	No	Assumed to be equivalent to fossil fuel emissions from transport of organic waste to composting facility.
	Fossil fuel emissions from transport of imported forage	CO_2	No	Assumed to be conservative as project scenario is likely to require less importation of feed.
Project	Project Parcels soil	CO_2	Yes	Additional CO_2 emissions from compost application may occur and are included.
		N_2O	Yes	Additional N_2O emissions from compost application may occur and are included.
		CH_4	No	Non-flooded soils can be a source or sink of Methane but fluxes are negligible
	Ruminants	CH_4	Yes	Methane emissions from enteric fermentation from ruminants grazing on the land.
	Emissions due to leaching	N_2O	No	Secondary emissions from leachates of the composted material are negligible due to the complex nature of compost and the low nitrogen content of compost.
	Fossil fuel emissions from transport of organic waste	CO_2	No	Assumed to be equivalent to fossil fuel emissions from transport

	to the compost facility			of organic waste to landfill.
	Fossil fuel emissions from transport of compost to project parcel and application	CO_2	Yes	Assumed to be additional to the fossil fuel emissions from transport of organic waste to landfill or composting facility.
	Fossil fuel emissions from transport of imported forage	CO_2	No	Assumed to be conservative as project scenario is likely to require less importation of feed.
	Emissions due to composting	CO_2	No	Carbon dioxide emissions released during composting are biogenic. These emissions are not quantified in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 4: Biological Treatment of Solid Waste and therefore are not included in this calculation of project emissions.
		CH_4	Yes/No	Some methane may be produced during composting. To avoid double deductions, this source of emissions shall be omitted in case the composting facility claims emission reductions for avoiding emissions from anaerobic decay of organic waste.
		N_2O	No	Nitrous oxide emissions during composting are negligible.

Table 2. Overview of included pools (baseline and project)

Pool	Included in emissions reductions quantification	Rationale
Above-ground non-woody biomass	No	The above-ground non-woody biomass pool will not be directly quantified in the protocol, however during decomposition some carbon from this pool will eventually enter the soil carbon pool that is accounted for and quantified by the methodology.
Below-ground non-woody biomass	No	The below-ground non-woody biomass pool will not be directly quantified in the protocol, however during decomposition some carbon from this pool will eventually enter the soil carbon pool that is accounted for and quantified by the methodology.
Litter	No	The litter pool will not be directly quantified in the protocol, however during decomposition some carbon from this pool will eventually enter the soil carbon pool that is accounted for and quantified by the methodology.
Dead wood	No	Not a major pool affected by project activities.
Soil	Yes	Potentially significantly affected by project activities. The increased forage production and the addition of compost are expected to increase the soil organic content.

B.3 Temporal Boundary

The project start date shall coincide with the first compost application event. The minimum project term will be 40 years due to the fact that the ERTs claimed as a result of the compost additions to grassland soils are calculated based on the stability of the "intermediate" and "passive" C pools being greater than 40 years (see Sections A.3 and D.2). The crediting period is defined by the ACR Standard as the finite length of time for which a GHG Project Plan is valid, and during which a project can generate offsets against its baseline scenario.[13] The crediting period for each project will be 10 years and validation of the GHG Project Plan will occur once per crediting period. Crediting periods are limited in order to require project proponents to reconfirm at set intervals that the baseline scenario remains realistic, credible, additional, and that the current best GHG accounting practice is being used. Since ACR places no limit on the number of crediting period renewals, the project proponent may renew the crediting period in 10-year increments thereafter, provided that the project still meets the protocol requirements. The

[13] The current version of the ACR Standard can be found online at http://americancarbonregistry.org/carbon-accounting/standards-methodologies/american-carbon-registry-standard

methodology allows for multiple compost applications as long as there are at least three years between each application and the new application rate is explicitly reviewed and approved by a Qualified Expert. The three-year rule, combined with the review of the Qualified Expert, is intended to allow enough time between compost additions so that any potential negative impacts on plant communities can be detected and mitigated before a new application is scheduled.

C. Procedure for Determining the Baseline Scenario and Demonstrating Additionality

Emission reductions from avoidance of anaerobic decomposition have very different additionality considerations than emission reductions from direct and indirect increases in SOC. Project proponents who are not claiming any ERTs from avoidance of anaerobic decomposition do not have to consider the additionality requirements related to this source of emission reductions, covered in Section C.1. Since all projects using this methodology will add compost to Grazed Grasslands, all project proponents shall follow the additionality requirements related to direct and indirect increases in SOC, covered in Section C.2.

C.1 Additionality of Emission Reductions from Avoidance of Anaerobic Decomposition

Project proponents shall use ACR's three-prong approach[14] to demonstrate additionality. Specifically, in cases where ERTs from landfill diversion are obtained, it must be demonstrated that the source material used for composting was diverted from a landfill or anaerobic manure storage facility. ERTs cannot be claimed in instances where the landfill or anaerobic processing facility that would otherwise receive the waste material cannot be identified, or if the facility from which source material was diverted already captures methane. Evidence must be provided demonstrating that the specific source of the waste material used for composting (e.g., the specific waste collector) has been deposited in a landfill or storage under anaerobic conditions (in the case of manure) for a period of five years prior to the project's starting date. Valid evidence includes economic analyses, reports, peer-reviewed literature, industry group publications, surveys, etc. Note that examples of the application of these approaches are provided in Section C.1.2.

C.1.1 Co-composting

Often, multiple waste sources are composted together to get an optimal composting C-to-N ratio and increase the waste streams that can be processed. This is referred to as co-composting. In case one of the materials used during co-composting is non-additional, the proportion of the waste that is additional shall be recorded and used in subsequent calculations in Section C.2 as parameter $f_{diverted}$. In case all the waste material is additional, $f_{diverted}$ shall be set to 1. The $f_{diverted}$ factor is used in subsequent calculations to discount any GHG benefits so that only additional benefits are counted.

[14] The three-prong test is described in detail in the ACR Standard.

C.1.2 Examples of determining additionality through diversion of waste materials

- Studies by *Biocycle Magazine*, referenced in a report published by the EPA in 2008,[15] estimate that, at a national level, 97.4% of solid food waste (e.g., milk solids, condemned animal carcasses, meat scraps, and pomace wastes from wineries) were landfilled in 2007. Therefore, compost made from solid food waste is additional without the need for any further evidence.
- The same report published by the EPA in 2008 estimated that 35.9% of the total quantity of yard waste was landfilled. Therefore, a project developer must demonstrate that the specific source of the waste material, i.e., the waste collector of a specific municipality, has landfilled the yard waste for a period of five years prior to the Project's starting date.
- California generates 750,000 dry tons of biosolids, the by-product of channeling human waste through treatment plants and collection systems (California Association of Sanitation Agencies). In total, 54% is land applied and 16% is composted according to statistics from CalRecycle, available at http://www.calrecycle.ca.gov/organics/biosolids/#Composting. Therefore, a project developer using compost derived from biosolids must demonstrate that the specific source of the biosolids, i.e., the biosolids of a specific municipality, have been landfilled in the past.
- The biosolids from sources that are already land-applied (currently 54%) are not compost and not considered additional under this methodology. However, these biosolids could potentially be co-composted by blending it with carbonaceous material such as paper diverted from landfills. The resulting compost is eligible to be used within this methodology on the condition that $f_{diverted}$ is set to the percentage of the compost feedstock (biosolids plus carbonaceous material) actually diverted from landfill.

C.2 Additionality of Emission Reductions from Increases in SOC

The additionality of emission reductions from direct or indirect increases in SOC related to the addition of compost to Grazed Grassland can be tested in a straightforward fashion using ACR's standard three-prong approach, based on Regulatory Surplus, Common Practice, and Implementation Barriers.

C.3 Baseline Determination

Once ACR's three-prong test is passed, the baseline management is set as a continuation of the historical management. The historical management is defined by acquiring the following three parameters for a period of at least five years[16] before the start of the Project:

- Stocking rates

[15] Municipal Solid Waste in the United States. 2007 Facts and Figures. Environmental Protection Agency Office of Solid Waste (5306P). EPA530-R-08-010. Available at http://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1001UYV.PDF

[16] Note that in areas with a longer history of fire, significant changes in plant cover, or other disturbances, more details may be needed to adequately parameterize PBM models.

- Stocking periods
- Incidence of fires

The historical grazing management shall be duly described. These management parameters and other site-specific parameters that are required to define the baseline are included in the list of parameters available at model validation (Section E.1). Key parameters such as the site-specific grazing intensity, soil properties, and climate will be required for all baseline model validation efforts. However, since process based models vary in the ancillary input parameters that they require, appropriate discretion on what must be included will be given to those tasked with validating the model for a given site.

Baseline stocking rate shall be the average of at least 3 of the last 5 years prior to the project start date. The project proponent shall select the most representative years to include and must provide a verifiable justification of the year selection in the GHG project plan.

D. Quantification of GHG Emission Reductions and Removals

D.1 Requirements for Models used for Quantifying GHG emissions and removals

This methodology does not prescribe a model to quantify changes in SOC and soil N_2O emissions. A variety of models are eligible to quantify GHG emissions and removals on the condition that (1) project developers demonstrate the use of the selected model is sufficiently accurate for their study area, as explained in the remainder of this section, and (2) an appropriate uncertainty deduction is applied. Either PBMs or empirical models such as emission factors may be used. Multiple models may be used during the carbon accounting. For example, it is allowed to use a PBM for one variable, such as SOC, and use a Tier-2 Emission Factor for N_2O emissions. The remainder of this section contains general requirements related to the use of Tier-2 Empirical Models and PBMs.

The uncertainty deduction shall have two components: one component related to the inherent, or structural, uncertainty from the model, and another component related to the variability of the input data, such as the variability of the N content in the compost, or the soil texture. Each of the three potential quantification approaches detailed below contains a section on how to calculate structural uncertainty. The structural uncertainty shall further be adjusted for aggregation. The input uncertainty shall be calculated using a Monte Carlo approach and using a 90% confidence level. The two sources of uncertainty, structural uncertainty and input uncertainty, shall simply be summed to calculate the total uncertainty. For the N_2O and ΔSOC components, the total uncertainty shall be calculated as:

$$u_{total} = \frac{u_{struct}}{\sqrt{n}} + u_{input}$$

u_{total}	=	Total uncertainty deduction [MT CO_2-eq]
u_{struct}	=	Structural uncertainty deduction related to the use of a specific model [MT CO_2-eq]
n	=	Number of Project Parcels or the total size of the Project Parcels in hectares divided by 250, whichever is smallest [-]
u_{input}	=	Input uncertainty deduction [MT CO_2-eq]

D.1.1 Tier-2 Empirical Models

Project proponents may develop Tier-2 Empirical Models, which may be used once they appear in the peer-reviewed scientific literature. Project Proponents shall justify in the GHG Project Plan that the sampling locations to create the regionally applicable Tier-2 Empirical Models are representative for the Project. Data from at least five sites across two years must be used to calculate the Tier-2 Empirical Model.

STRUCTURAL UNCERTAINTY FOR TIER-2 EMPIRICAL MODELS A bootstrapping method of resampling shall be used to estimate the deviation between measured and modeled emission reductions. The structural uncertainty shall be calculated as the half-width of the 90% confidence interval around the deviations and shall be deducted from the final ERTs.
INPUT UNCERTAINTY FOR TIER-2 EMPIRICAL MODELS The input uncertainty shall be calculated using simple propagation of errors around input parameters such as the quantity of carbon or nitrogen added through the compost additions. The error shall equal the half-width of the 90% confidence interval, e.g., from the error around the N content of the compost.

D.1.2 Process-based Biogeochemical Models (PBMs)

PBMs such as Century, Daycent,[17] EPIC, ROTH-C, or DNDC may be used on the condition that they are validated for the conditions of the Project Parcels and for the specific variable that is under consideration (i.e., annual change in SOC content, SOC content, or annual N_2O emissions). The PBM must be peer reviewed in at least three scientific publications. The PBMs indicated above meet the requirement on the scientific publications. In addition, the project proponents must develop an objective and unambiguous operating procedure to parameterize and run the PBMs. This procedure document must spell out how every input parameter shall be set. The applicability of the selected model is dependent on the soil type(s), climate, and broad management of the area in which the model is applied. Therefore, it is required to (1) validate the model for the conditions of the Project Parcels, and (2) specify the conditions under which the model's operating procedures remain valid. The validation of a model shall be conducted by comparing field measurements to model predictions. Once model validation has been completed, it does not need to be repeated.

The nature of geographic variability in conditions requires that some degree of judgment to be left to the model validator in order to determine the number of field measurement that will be adequate for local circumstances. Heterogeneous conditions may require more samples, while flatter or otherwise homogenous scenarios may require fewer.

The slope of the relation between modeled and measured values shall be between 0.9 and 1.1 as tested using two one-sided t-tests using a significance of 90%.

[17] Daycent is a version of the Century model with a daily time step, and these two models are essentially the same if it comes to simulating SOC. However, DAYCENT can also simulate soil N_2O and CH_4 emissions whereas Century cannot.

STRUCTURAL UNCERTAINTY FOR PBMs

For PBMs, the structural uncertainty for soil C sequestration shall be calculated as the half-width of the 90% confidence interval around the mean deviation between modeled and measured differences between baseline and project SOC quantities, multiplied by 44/12 to convert the uncertainty into CO_2-equivalents, as is commonly done in GHG accounting methodologies. This uncertainty shall be noted and subtracted from the final ERTs, as explained in Section D.4. An uncertainty for N_2O emissions shall be calculated similarly as the half-width of the 90% confidence interval around the mean deviation between modeled and measured differences of project N_2O emissions, except for a multiplication with 310 x 44 / 28, to account for the radiative forcing and molecular weight of N_2O.

INPUT UNCERTAINTY FOR PBMs

The input uncertainty for PBMs shall be calculated using a Monte Carlo analysis based on a multivariate distribution of the input parameters. At least 200 different draws out of this multivariate distribution for both the Baseline Scenario and the Project Scenario and subsequent model simulations must be executed. For each of the draws of the distribution, one emission reduction is calculated by subtracting the Baseline emissions from the Project emissions. Calculate the uncertainty as the value corresponding to the 10% quantile for the distribution of values.

D.2 Baseline Emissions

D.2.1 General Equation

If avoided landfill emissions are claimed by the project, the emissions of the waste material when deposited in a landfill must be calculated for each project parcel separately using the following equations:

[EQ 1]

$$BE(y,i) = f_{diverted}(BE_{landfill}(y,i)) + BE_{\Delta SOC}(y,i) + BE_{N2O}(y,i)$$

Sub-equations for Components:

[EQ 2]

$$BE_{landfill,}(y,i) = BE_{landfill.CH4} - \left(\frac{\sum_{i=1}^{j} W_j \cdot DOC_j \cdot DOC_f}{40} \cdot \frac{44}{12}\right)$$

[EQ 3]

$$BE_{\Delta SOC}(y,i) = A(i) \cdot \Delta SOC(y,i) \cdot \frac{44}{12}$$

[EQ 4]

$$BE_{N2O}(y,i) = A(i) \cdot CE_{N2O}(y,i)$$

Where:

$BE(y,i)$	=	The total sum of the baseline emissions associated with project parcel i during year y. See EQ 1 above. [MT CO_2-eq yr^{-1}]
$f_{diverted}$	=	The percentage of the waste source that is additional. See Section C.1.1.
$BE_{landfill}(y,i)$	=	The cumulative baseline emissions of Methane and Carbon Dioxide from waste material at the landfill under the baseline scenario during year y. To be set to 0 when emission reductions at the landfill claimed by an entity other than the Project Proponents. See EQ 2 above. [MT CO_2-eq yr^{-1}]
$BE_{landfil,CH4}(y,i)$	=	The cumulative baseline Methane emissions from waste material at the landfill or waste storage pond under the baseline scenario during year y. To be set to 0 when emission reductions from avoidance of anaerobic emissions are claimed by an entity other than the Project Proponents. [MT CO_2-eq yr^{-1}]
W_j	=	Amount of organic waste type j prevented from disposal, expressed as dry mass. To be set to 0 when emission reductions from avoidance of anaerobic emissions are claimed by an entity other than the Project Proponents.
DOC_j	=	Fraction of waste type j that is degradable organic carbon (by weight). To be set to 0 when emission reductions from avoidance of anaerobic emissions are claimed by an entity other than the Project Proponents.
DOC_f	=	Fraction of degradable organic carbon (DOC) that fully decomposes to CO_2. To be set to 0 when emission reductions from avoidance of anaerobic emissions are claimed by an entity other than the Project Proponents.
$\frac{44}{12}$	=	Factor to convert the mass of C to CO_2.
$BE_{\Delta SOC}(y,i)$	=	Annual CO_2 emissions from the change in soil organic C for project parcel i during year y of the baseline scenario, calculated using a model that

		meets the requirements of Section D.1. The sign of this component is determined by the baseline trends in SOC, which can be either positive when soil is a net source of CO_2 or negative when it is net sink of CO_2. See EQ 3 above. [MT CO_2-eq yr^{-1}]
$A(i)$	=	Size of project parcel i. [ha]
$\Delta SOC(y,i)$	=	Change in baseline soil organic carbon of project parcel i during year y of the baseline scenario, calculated using a model that meets the requirements of Section D.1. [MT C ha^{-1} yr^{-1}]
$BE_{N2O}(y,i)$	=	Cumulative baseline Nitrous Oxide emissions from soils of the project parcel i during year y of the baseline scenario, expressed in CO_2-eq. To be calculated using a model that meets the requirements of Section D.1. See EQ 4 above. [MT CO_2-eq yr^{-1}]
$CE_{N2O}(y,i)$	=	Annual N_2O emissions rate from soils of project parcel i during year y of the baseline scenario. To be calculated using a model that meets the requirements of Section D.1. [MT CO_2-eq ha^{-1} yr^{-1}]

Note that the "44/12" factor converts a mass of carbon into a mass of Carbon Dioxide. In addition, the quantity $W_j \cdot DOC_j \cdot DOC_f$ represents the cumulative mass of carbon that is decomposed after 40 years in a landfill for waste material. Therefore, $\frac{44}{12}\frac{\sum_{i=1}^{j} W_j \cdot DOC_j . DOC_f}{40}$ represents the annual CO_2 emissions from decomposition of the waste material in the landfill under the baseline scenario.

D.2.2 Quantification Procedure

The value $BE_{landfill,CH4}(y,i)$ shall be calculated as the quantity $BE_{CH4,SWDS,y}$ using the CDM tool "Tool to determine Methane emissions avoided from disposal of dumping waste at a solid waste disposal site." The quantities W_j, DOC_j, and DOC_f shall be set according to this CDM tool. Finally, the quantity $BE_{\Delta SOC}(y,i)$ shall be calculated using a model that meets the requirements of Section D.1.

D.3 Project Emissions

D.3.1 General Equation

[EQ 5]

$$PE(y,i) = PE_{\Delta SOC}(y,i) + PE_{N2O}(y,i) + \ PE_{fuel}(y,i) + PE_{compost,CH4}(y,i)$$

Sub-Equations for Components

[EQ 6]

$$PE_{\Delta SOC}(y,i) = A(i) \cdot \left(\frac{\Delta SOC_d(40)}{40} + \Delta SOC_i(y,i) \right) \cdot \frac{44}{12}$$

[EQ 7]

$$PE_{N2O}(y,i) = A(i) \cdot CE_{N2O}(y,i)$$

Where:

$PE(y,i)$	=	The total sum of the project emissions during year y. [MT CO_2-eq yr^{-1}]
$PE_{\Delta SOC}(y,i)$	=	Annual CO_2 emissions from the change in soil organic C for project parcel i during year y of the project, calculated using a model that meets the requirements of Section D.1. The sign of this component is determined by the baseline trends in SOC, which can be either positive when soil is a net source of CO2 or negative when it is net sink of CO_2. See EQ 6 above. [MT CO_2-eq yr^{-1}]
$A(i) \cdot$	=	Size of project parcel i. [ha]
$\Delta SOC_d(40)$	=	Change in carbon from added compost remaining in the soil at year 40. To be calculated using a model that meets the requirements of Section D.1 [MT C ha^{-1} yr^{-1}]
$\Delta SOC_i(y,i)$	=	Annual indirect change in soil carbon due to increases in plant productivity during year. To be calculated using a model that meets the requirements of Section D.1. [MT C ha^{-1} yr^{-1}]
$\frac{44}{12}$	=	Factor to convert the mass of C to CO_2.
$CE_{N2O}(y,i)$	=	Cumulative Nitrous Oxide emissions from soils of the project parcel i during year y of the project, expressed in CO_2-eq. To be calculated using a model that meets the requirements of Section D.1. See EQ 7 above. [MT CO_2-eq yr^{-1}]
$PE_{N2O}(y,i)$		Annual N_2O emissions rate from soils of project parcel i during year y of the project. To be calculated using a model that meets the requirements of Section D.1. [MT CO_2-eq ha^{-1} yr^{-1}]
$PE_{fuel}(y,i)$	=	Fuel emissions from transportation to the project parcel and application of the organic material on the land during year y. [MT CO_2-

eq yr^{-1}]

$PE_{compost,CH4}(y,i)$	=	At a year when compost is added, e.g., when $y = 1$, the Methane emissions emitted during composting of the organic material, expressed in CO_2-eq. At all other years, this quantity is to be set to 0. When emission reductions from avoidance of anaerobic emissions are claimed by an entity other than the Project Proponents, this quantity is to be set to 0 at all times to avoid double discounting [MT CO_2-eq yr^{-1}]

Because $\Delta SOC_d(40)$ represents the compost carbon remaining after 40 years, $\frac{\Delta SOC_d(40)}{40}$ represents the fraction of the compost carbon remaining that can be claimed as a GHG benefit for every year of the project period.

D.3.2 Quantification Procedure

The quantities $\Delta SOC_d(40)$, $\Delta SOC_i(y)$, and $PE_{N2O}(i,y)$ shall be calculated using a Tier-2 Empirical Model, or a PBM. If a PBM is used that is based on conceptual C-pools, only pools that have a turnover time of greater than 2 years shall be counted towards $\Delta SOC_d(40)$ and $\Delta SOC_i(y)$. This provision is included to avoid incorporating carbon sources that are readily decomposable as carbon sequestration. $\Delta SOC_d 40$ and $\Delta SOC_i(y)$ must be *reduced* by an appropriate discounting factor, while $PE_{N2O}(i,y)$ must be increased by an appropriate discounting factor, as specified in Section D.1.

$PE_{fuel}(i,y)$ is the sum of the emissions from fuel use from transportation and the fuel use from application of the compost. The fuel use from transportation of the compost shall be calculated using the CDM tool “Project and leakage emissions from road transportation of freight.” The fuel use from application of the compost shall be calculated using the CDM tool “Tool to calculate project or leakage CO2 emissions from fossil fuel combustion.”

The project proponent must account for any increase in enteric emissions associated with the project activity, likely due to an increased stocking rate. The ACR Tool for Tier I Estimation of Emissions from Livestock Management Projects shall be used to calculate the net enteric emissions. The project proponent must enter all baseline and project scenario data required by the “2. Enteric” tab in the tool (all other data input tabs can be excluded). The value for the net emissions from Enteric shall be pulled from cell J13 of the “6. X-ANTE” tab and included in equation 8 below. If the result is a positive number (emission reductions), it will be considered “zero” for the purposes of conservativeness.

$PE_{compost,CH4}(i)$ shall be calculated using the most recent default emission factor available from the IPCC for the CH_4 emissions from biological treatment of waste.[18]

[18] As of the writing of this methodology, the emissions factor is found in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste, Chapter 4: Biological Treatment of Solid Waste.

D.4 Summary of GHG Emission Reduction and/or Removals

[EQ 8]

$$ER_y = \sum_{i=1}^{nrParcels} \left(PE(y,i) - BE(y,i)\right) + \Delta CH_4enteric - u_{total}$$

Where:

ER_y	=	GHG emissions reductions and/or removals in year y [tCO_2-eq yr^{-1}]
$nrParcels$	=	Number of individual Project Parcels
$PE(y,i)$	=	Project emissions in year y for individual parcel i [$MTCO_2$-eq yr^{-1}]
$BE(y,i)$	=	Baseline emissions in year y for individual parcel i [$MTCO_2$-eq yr^{-1}]
$\Delta CH_4enteric$	=	Enteric emissions associated with an increase in stocking rate over each project parcel. Either enter zero, or the value from cell J13 of the 6.T-XANTE tab of the *ACR Tool for Estimation of Emissions from Livestock Management Projects*, whichever is less. [$MTCO_2$-eq yr^{-1}]
u_{total}	=	Total uncertainty deduction [MT CO_2-eq]

D.5 Leakage

Emissions leakage refers to instances where activities to reduce emissions from a project parcel may result in increased emissions due to activities and market shifts occurring at locations beyond the project boundaries. Available field research suggests that the addition of compost to grasslands will generally increase soil carbon and the production of forage for livestock. Although not directly connected to the project activities, increases or decreases in stocking rate have been accounted for in this methodology in the spirit of whole-system accounting and conservativeness.

Voluntary and significant stocking rate reductions (more than three percent of the baseline) will make the project ineligible for crediting over the quantification period, until the stocking rate has returned to within -3% of the baseline level. Monitoring and reporting would be required to continue to ensure permanence of sequestered carbon. A leakage deduction will not need to be taken for any stocking rate reductions of greater than 3% from the baseline if justifiably attributable to verifiable instances of natural disaster, disease or otherwise that significantly reduces the stocking rates involuntarily. These circumstances must be verified by an accredited VVB with sufficient documentation including an attestation by the Proponent, demonstrating that this circumstance would have also affected the baseline in a business as usual situation.

E. Monitoring

E.1 Data and Parameters Available at Validation

Various data elements related to compost, soil, weather, and management must be available at model validation. The specific data elements required are detailed below, and explicitly outlined in Appendix A.

- **Compost**. The following data must be available for each batch of compost. Unless sound data for these parameters are available (e.g., as a result from a certification), the compost must undergo laboratory tests.
    - The **carbon concentration** is required to convert mass of dry compost to mass of carbon added, which is a property that is required by a model.
    - The **nitrogen concentration** is required to convert mass of dry compost to mass of nitrogen added, which is needed to verify the applicability conditions and may also be required for the model used.
    - The **C:N ratio** is required to be calculated based on the aforementioned data availability.
    - It is advised, but not required, to include the **phosphorus concentration** in the elemental analysis, as this may improve the models' ability to simulate changes in SOC related to compost addition.
    - The **bulk density** is required to convert a volume of compost, a very common unit used by compost facilities, spreaders, and transporters, into a mass of compost.
    - The **moisture content** is required to convert a mass of moist compost into dry compost.
    - The **pH** of the compost must be measured and recorded

  In addition, the following information shall be obtained if available:
    - Source of the compost raw materials
    - Fate of the organic matter under baseline conditions
- **Soil**. At least three soil samples per parcel shall be taken within each stratum representing at least 0-20 cm. If the relative standard error among the three samples is greater than 20%, more samples shall be taken until the relative standard error is less than 20%. Project developers may choose to take more and deeper samples than this minimum requirement, which is beneficial in improving both model runs and the potential for demonstrating carbon sequestration at greater depths. Samples shall not be composited. The following measurements shall be conducted on the soil samples based on standard analytical protocols described in the Soil Science Society of America Methods of Soil Analysis (Sparks et al. 1996):
    - Total soil carbon
    - Soil texture
    - Soil bulk density
    - Soil pH

  Note that the project developer is allowed to measure the soil carbon at the start of the project *after* compost application on reference locations within the Project Parcels that did not receive the compost application. The latter is feasible when reference locations are shielded from compost application by putting a tarp at that location and removing the compost that is deposited on the tarp before soil carbon analysis.

- **Historical weather**. Daily minimum and maximum temperatures and rainfall shall be obtained for a period of five years before the start of the Project. Historical weather data must come from the nearest weather station or other published weather records (such as Daymet).
- **Project weather**. Daily minimum and maximum temperatures and rainfall shall be obtained through the duration of the Project. This data must come from the nearest weather station or other published weather records (such as Daymet).
- **Historical management**. The following parameters shall be provided for each stratum for a period of at least 5 years before the start of the project. Additional years of data are highly recommended if significant changes in land cover or management are known to have occurred
  - Stocking rates
  - Stocking periods
  - Incidence of fires
- **Project management**. The following parameters shall be provided for each stratum of a project
  - Project population
  - Stocking rate
  - Stocking period
  - Average stocking rate (average over all project years)
  - Minimum stocking rate
  - Maximum stocking rate
  - Incidence of fires
- **Plants and plant communities**. A land assessment by a Qualified Expert must be provided that this consistent with standard NRCS ecological site descriptions[19]. This land assessment report should include a stratification of the land and a description of plant productivity (which is inclusive of species type and forage quality) into three groups: “poor”, “medium”, or “high”. Values of net primary productivity are required in order to better determine yield response.. These values should be obtained through the creation of an exclusion area where livestock are not able to graze so that primary productivity can be measured in dry matter/unit area. The land assessment report shall contain a broad description of the plant communities, percentage cover of natives as well as any problems with invasive weeds before the start of the project. Finally, the land assessment report shall also contain an assessment of the fire risk.

In addition to the parameters described above, various additional soil and site parameters may be needed to parameterize the model runs. The onus is on the project developer to demonstrate that a model was used and parameterized correctly.

[19] Information on NRCS ecological site descriptions may be found online at http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/ecoscience/desc/

E.2 Data and Parameters Recorded during Compost Application

In addition, a description of the application procedure must be provided. This description must include:

- Application date
- Machinery used
- Application method
- Broadcast rate (tons/ha)
- Rationale for application procedure and reference source if available

Receipts of compost purchase, transportation, and application shall be kept and made available to the validator. In addition, it is strongly recommended to take pictures during the application of the compost. All data collected as part of monitoring must be archived electronically and be kept at least for two years after the end of the project crediting period.

E.3 Data and Parameters Monitored after Compost Application

Total soil carbon, texture, bulk density and pH shall be measured for the 0-20cm soil depth at the start of the project and at least every 10 years thereafter as described in Section E.1. In addition, an update of the land assessment report by a Qualified Expert shall be conducted two and five years after compost application.

Actual weather shall be recorded from the same weather station used during model validation. In addition, Stocking Rates and periods shall be provided for each stratum for every year after the start of the project. Every incidence of wildfire shall be reported and used in ex-post simulation, if the selected model allows.

E.4 Updating Models and Model Structural Uncertainty Deduction

The model uncertainty must be updated at least every 10 years, which is also the time frame of a project's crediting period extension. However, it is allowed to update a model's structural uncertainty deductions more frequently as new field data becomes available during a project's crediting period. The new structural uncertainty deductions must be proposed in a monitoring report and explicitly approved by a VVB before ERTs are issued using the new structural uncertainty deductions. The calculation of Baseline and Project emissions must always use the same structural uncertainty deductions.

In addition to updating the structural uncertainty deduction, it is allowed to use (a) different model(s) after the start of the project. For example, it is allowed to switch from a Tier-2 Empirical Model to a PBM. All requirements related to the selection of the model(s) and the calculation of its/their structural uncertainty deduction must be met. This switch must be proposed in a monitoring report and explicitly approved by a VVB before ERTs are issued using the new model(s). The calculation of Baseline and Project emissions must always use the same modeling approach.

F. Permanence

Projects must be consistent with the ACR Standards for permanence, which require proponents to sign ACR's risk mitigation agreement.[20] This risk mitigation agreement legally requires the project proponents to conduct a risk assessment using the latest ACR-approved Non-Permanence Risk Analysis and Buffer Determination tool[21]. The result of this assessment is an overall risk category for the project, translating into a percentage or number of ERTs that the project proponent must deposit, at each new ERT issuance, into a shared non-permanence buffer pool managed by ACR. For instance, ERTs contributed from the Project or those purchased from other Projects may be used to satisfy this buffer pool requirement. Alternatively, the proponent may also meet its legal obligations by providing evidence of sufficient insurance coverage with an ACR-approved insurance product. Reversals need only be fully compensated when they occur during the period in which monitoring is required (i.e. during the minimum project term).

In addition, the proponent shall take measures to reduce the risk of reversal from the following types of reversals that may occur, namely inundation, land use conversion and tillage. Every incidence of inundation due to extensive rainfall or large scale flooding of rivers and streams that lasts for longer than two months in a given crediting year shall be reported. All areas that were inundated for longer than two months shall be excluded from crediting during that year. It is likely that the boundaries of the flooded area do not coincide with the boundaries of strata established during stratification. Therefore, the flooded areas shall be cut out from existing strata for the duration of the year during which the flood happened. If the flood straddles a crediting year, ERTs may not be generated for both years during which the flood occurred. Unless specific circumstances indicate that that the Project Proponent flooded the parcel intentionally, inundation shall be considered a non-intentional reversal according to terms of the risk mitigation agreement.

Any conversion of a project parcel to any other land use than Grazed Grassland, such as annual arable crops or development, will immediately exclude this parcel from generating future ERTs. Unless the soil carbon loss due to the conversion on this Project Parcel is duly replaced by acquiring ERTs from this or other projects and project types, all ERTs from previously stored soil carbon shall be considered a reversal of previously credited ERTs. In addition to the aforementioned risk mitigation mechanisms discussed above, the project proponent may replace the reversed ERTs with ERTs issued from other project parcels within the same project within two years of the date of the conversion. Note that even after replacing the ERTs lost to conversion, the project parcel that was converted must be permanently excluded from issuing ERTs. All other Project Parcels within the Project are not affected by one project

[20] The current version of the ACR Standard can be found online at http://americancarbonregistry.org/carbon-accounting/standards-methodologies/american-carbon-registry-standard

[21] The Tool for AFOLU Non-Permanence Risk Analysis and Buffer Determination can be found online at http://www.v-c-s.org/sites/v-c-s.org/files/Tool%20for%20AFOLU%20Non-Permanence%20Risk%20Analysis%20and%20Buffer%20Determination.pdf

parcel being converted to another land-use. In case only part of a parcel was converted to another land use, it is allowed to pro-rate the reversed ERTs or re-purchase ERTs based on the relative proportion of the conversion within the parcel. Land use conversion shall be considered an intentional reversal according to terms of the risk mitigation agreement.

In the unlikely case that a tillage event occurs on the Project Parcel without a conversion of the grassland to agricultural or any other land use, all soil carbon ERTs previously issued from this Project Parcel will be considered to have been reversed unless the carbon losses resulting from the tillage event on the Project Parcel are duly accounted for and compensated by retiring existing ERTs from the current or other projects and project types. Similarly to land conversions, this carbon loss shall be verified in a monitoring report and must be verified by a VVB. In addition, unless such a true-up occurs, the project parcel shall be permanently excluded from issuing ERTs. Tillage shall be considered an intentional reversal according to terms of the risk mitigation agreement.

G. References and Sources

Adams, M., J. Crawford, D. Field, N. Henakaarchchi, M. Jenkens, A. McBratney, V.R. de Courcelles, K. Singh, U. Stockmann, and I. Wheeler 2011. Managing the soil-plant system to mitigate atmospheric CO2. Soil Carbon Sequestration Summit Paper. January 31, 2011. Available online at: http://ussc.edu.au/s/media/docs/other/Science_Review_Paper.pdf

Allen V.G., C. Batello, E.J. Berretta, J. Hodgson, M. Kothmann, X. Li, J. McIvor, J. Milne, C. Morris, A. Peeters, M. Sanderson. 2011. The Forage and Grazing Terminology Committee. "An international terminology for grazing lands and grazing animals*." Grass and Forage Science.* 66: 2–28.

Bremer, E. 2009. *Potential for Reductions in Greenhouse Gas Emissions from Native Rangelands in Alberta* – Technical Scoping Document. Symbio Ag Consulting for Alberta Agriculture and Rural Development.

Brown, S., M. Cotton, S. Messner, F. Berry, D. Norem. 2009. *Methane avoidance from composting.* An issue paper for the Climate Action Reserve.

Cai, Z. C., and S. W. Qin. 2006. "Dynamics of Crop Yields and Soil Organic Carbon in a Long-Term Fertilization Experiment in the Huang-Huai-Hai Plain of China." *Geoderma.* 136(3–4):708–15.

Canali, S., A. Trinchera, F. Intrigliolo, L. Pompili, L. Nisini, S. Mocali, and B. Torrisi. "Effect of Long Term Addition of Composts and Poultry Manure on Soil Quality of Citrus Orchards in Southern Italy." *Biology and Fertility of Soils*. 40(3): 206–10.

Chou, W., W. Silver, R. Jackson, A. Thompson, B. Allen-Diaz. 2008. "The sensitivity of annual grassland carbon cycling to the quantity and timing of rainfall." *Global Change Biology.*14: 1382-1394.

Conant, R.T. 2010. Challenges and opportunities for carbon sequestration in grassland systems. FAO Integrated Crop Management Series Vol. 9.

Conant, R.T., and K. Paustian. 2002. "Potential Soil Carbon Sequestration in Overgrazed Grassland Ecosystems." *Global Biogeochemical Cycles.* 16(4):1143.

DeLonge, M. S., R. Ryals, W. L. Silver. 2013 "A Lifecycle Model to Evaluate Carbon Sequestration Potential and Greenhouse Gas Dynamics of Managed Grasslands." Ecosystems 16(6): 962–979.

Derner, J.D., and G.E. Schuman. 2007. "Carbon Sequestration and Rangelands: A Synthesis of Land Management and Precipitation Effects." *Journal of Soil and Water Conservation.* 62(2): 77–85.

FAOSTAT. 2009. Statistical Database 2007. Rome.

Ippolito, J. A., K. A. Barbarick, M. W. Paschke, and R. B. Brobst. 2010. "Infrequent Composted Biosolids Applications Affect Semi-Arid Grassland Soils and Vegetation." *Journal of Environmental Management.* 91(5): 1123–30.

Kowaljow, E., M.J. Mazzarino, P. Satti, and C. Jiménez-Rodríguez. 2010. "Organic and Inorganic Fertilizer Effects on a Degraded Patagonian Rangeland." Plant and Soil 332(1–2): 135–45.

Lal, R. 2002. "Soil Carbon Dynamics in Cropland and Rangeland." *Environmental Pollution*. 116(3):353–62.

Mantovi, P., G.Baldoni, and G. Toderi. 2005. "Reuse of Liquid, Dewatered, and Composted Sewage Sludge on Agricultural Land: Effects of Long-Term Application on Soil and Crop." *Water Research*. 39(2–3): 289–96.

Ryals, R. and W.L. Silver. 2013. "Effects of organic matter amendments on net primary productivity and greenhouse gas emissions in annual grasslands." *Ecological Applications.* 23:49-59.

Ryals, R., M. Kaiser, M.S. Torn, A.A. Berhe, and W.L. Silver. 2014. "Impacts of Organic Matter Amendments on Carbon and Nitrogen Dynamics in Grassland Soils." *Soil Biology and Biochem*istry. 68: 52–61.

Sparks, D.L., Page, A.L., Helmke, P.A., Loeppert, R.H., Soltanpour, P.N., Tabatabai, M. A., ... & Sumner, M. E. (1996). Methods of soil analysis. Part 3-Chemical methods. Soil Science Society of America Inc.

Stromberg, M.R., J.D. Corbin, and C.M. D'Antonio, eds. *California grasslands: ecology and management*. Univ of California Press, 2007.

Sullivan, T.S., M.E. Stromberger, M.W. Paschke, and J.A. Ippolito. 2006. "Long-Term Impacts of Infrequent Biosolids Applications on Chemical and Microbial Properties of a Semi-Arid Rangeland Soil." *Biology and Fertility of Soils*. 42(3):258–66.

Trumbore, S. E. 1997. Potential responses of soil organic carbon to global environmental change. *Proceedings of the National Academy of Sciences,* 94**:**8284-8291.

Walter, I., F. Martínez, and G. Cuevas. 2006. "Plant and Soil Responses to the Application of Composted MSW in a Degraded, Semiarid Shrubland in Central Spain." *Compost Science and Utilization*. 14(2):147–54.

Walton, M., J.E. Herrick, R.P. Gibbens, and M.D. Remmenga. 2001"Persistence of Municipal Biosolids in a Chihuahuan Desert Rangeland 18 Years After Application." *Arid Land Research and Management* 15(3): 223–32.

G.1 Sources

This methodology has adopted aspects of the following sources for its carbon accounting:

- ACR's Grazing Land and Livestock Management (GLLM) Methodology, available at http://americancarbonregistry.org/carbon-accounting/standards-methodologies/grazing-land-and-livestock-management-gllm-ghg-methodology
- "Adoption of sustainable agricultural land management (SALM)," available at http://www.v-c-s.org/sites/v-c-s.org/files/SALM%20Methodolgy%20V5%202011_02%20-14_accepted%20SCS.pdf, submitted to and approved by the Verified Carbon Standard (VCS); developed by the World Bank's BioCarbon fund
- Clean Development Mechanism (CDM) "Tool to determine Methane emissions avoided from disposal of dumping waste at a solid waste disposal site," available at http://cdm.unfccc.int/EB/041/eb41_repan10.pdf
- CDM tool "Project and leakage emissions from road transportation of freight," available at http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-12-v1.pdf
- CDM "Tool to calculate project or leakage CO_2 emissions from fossil fuel combustion," available at http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-03-v2.pdf
- "Organic Waste Composting Project Protocol," (Version 1.0), available at http://www.climateactionreserve.org/how/protocols/organic-waste-composting/, approved for use under the Climate Action Reserve.

Appendix A: Parameter List

A.1 Parameters for Baseline and Project Emissions, and Overall Emissions Reductions and/or Removals Quantification

Parameter	$BE(y,i)$
Units	MT CO_2-eq yr^{-1}
Description	Sum of baseline emissions associated with project parcel *i* during year *y*
Relevant Section	D.2, D.4
Relevant Equation(s)	1, 8
Source of Data	Calculated in equation 1
Data Requirements	$BE_{landfill}(y,i)$, $BE_{landfill,CH4}(y,i)$, $BE_{\Delta SOC}(y,i)$
Collection Procedure	Based on calculations from equations 2, 3, and 4
Revision Frequency	At the start of each crediting period
Comments	

Parameter	$f_{diverted}$
Units	%
Description	The percentage of the waste source that is additional
Relevant Section	C.1.1, C.1.2, D.4
Relevant Equation(s)	1
Source of Data	Determination through 8.1.1
Data Requirements	Compost source materials and additionality
Collection Procedure	Project Proponent obtains records of waste diverted from landfill to compost facility.
Revision Frequency	Each time Project Proponent uses new composting facility.
Comments	

Parameter	$BE_{landfill}(y,i)$
Units	MT CO_2-eq yr^{-1}
Description	The cumulative baseline emissions of Methane and Carbon Dioxide from waste material at the landfill under the baseline scenario during year y
Relevant Section	D.2
Relevant Equation(s)	1, 2
Source of Data	Calculated in equation 2
Data Requirements	$BE_{landfill.CH4}$, W_j, DOC_j , DOC_f
Collection Procedure	Project Proponent obtains records of waste diverted from landfill to compost facility.
Revision Frequency	Each time Project Proponent uses new composting facility
Comments	To be set to 0 when emission reductions at the landfill claimed by an entity other than the Project Proponents

Parameter	$BE_{landfill,CH4}(y,i)$
Units	MT CO_2-eq yr^{-1}

Description	The cumulative baseline Methane emissions from waste material at the landfill or waste storage pond under the baseline scenario during year y
Relevant Section	D.2
Relevant Equation(s)	2
Source of Data	Quantity $BE_{CH4,SWDS,y}$ using the CDM tool "Tool to determine Methane emissions avoided from disposal of dumping waste at a solid waste disposal site"
Data Requirements	W_j and IPCC factors
Collection Procedure	Project Proponent obtains records of waste diverted from landfill to compost facility.
Revision Frequency	Each time Project Proponent uses new composting facility
Comments	To be set to 0 when emission reductions from avoidance of anaerobic emissions are claimed by an entity other than the Project Proponents

Parameter	W_j
Units	Tons of dry mass
Description	Amount of organic waste type j prevented from disposal, expressed as dry mass
Relevant Section	D.2
Relevant Equation(s)	2
Source of Data	Uncomposted organic waste diverted from landfill
Data Requirements	Tons and type of organic waste prevented from disposal
Collection Procedure	Project Proponent obtains records of waste diverted from landfill to compost facility
Revision Frequency	Each time Project Proponent uses new composting facility
Comments	To be set to 0 when emission reductions from avoidance of anaerobic emissions are claimed by an entity other than the Project Proponents

Parameter	DOC_j
Units	%
Description	Fraction of waste type j that is degradable organic carbon (by weight)
Relevant Section	D.2
Relevant Equation(s)	2
Source of Data	Characteristics of waste type j
Data Requirements	Fraction of degradable organic carbon(by weight) in the waste type j
Collection Procedure	Project Proponent obtains records of waste diverted from landfill to compost facility.
Revision Frequency	Each time Project Proponent uses new composting facility
Comments	To be set to 0 when emission reductions from avoidance of anaerobic emissions are claimed by an entity other than the Project Proponents

Parameter	DOC_f
Units	%
Description	Fraction of degradable organic carbon (DOC) that fully decomposes to CO_2.
Relevant Section	D.2

Relevant Equation(s)	2
Source of Data	Characteristics of DOC
Data Requirements	W_j and amount of DOC in compost that fully decomposes to CO_2.
Collection Procedure	Project Proponent obtains records of waste diverted from landfill to compost facility.
Revision Frequency	Each time Project Proponent uses new composting facility
Comments	To be set to 0 when emission reductions from avoidance of anaerobic emissions are claimed by an entity other than the Project Proponents

Parameter	$BE_{\Delta SOC}(y,i)$
Units	MT CO_2-eq yr^{-1}
Description	Annual CO_2 emissions from the change in soil organic C for project parcel i during year y of the baseline scenario. The sign of this component is determined by the baseline trends in SOC, which can be either positive when soil is a net source of CO_2 or negative when it is net sink of CO_2.
Relevant Section	D.2
Relevant Equation(s)	3
Source of Data	Model estimates
Data Requirements	$A(i)$, $\Delta SOC(y,i)$
Collection Procedure	Calculated from equation 3
Revision Frequency	At the start of each crediting period
Comments	

Parameter	$A(i)$
Units	hectares
Description	Size of project parcel i
Relevant Section	D.2, D.3
Relevant Equation(s)	2, 6, 7
Source of Data	Project Proponent records
Data Requirements	Coordinates and area of project parcels
Collection Procedure	Project Proponents will collect and record area of participating project parcels.
Revision Frequency	At the start of each crediting period
Comments	

Parameter	$\Delta SOC(y,i)$
Units	MT C ha^{-1} yr^{-1}
Description	Change in baseline soil organic carbon of project parcel i during year y of the baseline scenario
Relevant Section	D.2
Relevant Equation(s)	3
Source of Data	
Data Requirements	
Collection Procedure	To be calculated using a model that meets the requirements of Section D.1.
Revision Frequency	At the start of each crediting period
Comments	

Parameter	$BE_{N2O}(y,i)$
Units	MT CO_2-eq yr^{-1}
Description	Cumulative baseline Nitrous Oxide emissions from soils of the project parcel i during year y of the baseline scenario, expressed in CO_2-eq.
Relevant Section	D.2
Relevant Equation(s)	4
Source of Data	Model outputs and Project Proponent records
Data Requirements	$A(i)$, $CE_{N2O}(y,i)$
Collection Procedure	Calculated from equation 4
Revision Frequency	At the start of each crediting period
Comments	

Parameter	$CE_{N2O}(y,i)$
Units	MT CO_2-eq ha^{-1} yr^{-1}
Description	Annual N_2O emissions rate from soils of project parcel i during year y of the baseline scenario.
Relevant Section	D.2
Relevant Equation(s)	4
Source of Data	Model input data requirements, multiple sources
Data Requirements	Model specific
Collection Procedure	To be calculated using a model that meets the requirements of Section D.1
Revision Frequency	At the start of each crediting period
Comments	

Parameter	$PE(y,i)$
Units	MT CO_2-eq yr^{-1}
Description	The total sum of the project emissions during year y
Relevant Section	D.3
Relevant Equation(s)	6, 8
Source of Data	Calculated in equation 5
Data Requirements	$PE_{\Delta SOC}(y,i)$, $PE_{N2O}(y,i)$, $PE_{fuel}(y,i)$, $PE_{compost,CH4}(y,i)$
Collection Procedure	Based on calculations from equations 6 and 7
Revision Frequency	Project year (annually)
Comments	

Parameter	$PE_{\Delta SOC}(y,i)$
Units	MT CO_2-eq yr^{-1}
Description	Annual CO_2 emissions from the change in soil organic C for project parcel *i* during year *y* of the project
Relevant Section	D.3
Relevant Equation(s)	5, 6
Source of Data	Model outputs and Project Proponent records
Data Requirements	$A(i)$, $\Delta SOC_d(40)$, $\Delta SOC_i(y,i)$

Collection Procedure	Calculated in equation 6
Revision Frequency	Project year (annually)
Comments	The sign of this component is determined by the baseline trends in SOC, which can be either positive when soil is a net source of CO2 or negative when it is net sink of CO_2.

Parameter	$\Delta SOC_d(40)$
Units	MT C ha^{-1} yr^{-1}
Description	Change in carbon from added compost remaining in the soil at year 40
Relevant Section	D.3
Relevant Equation(s)	6
Source of Data	Model input data requirements, multiple sources
Data Requirements	Model specific
Collection Procedure	To be calculated using a model that meets the requirements of Section D.1.
Revision Frequency	Project year (annually)
Comments	

Parameter	$\Delta SOC_i(y, i)$
Units	MT C ha^{-1} yr^{-1}
Description	Annual indirect change in soil carbon due to increases in plant productivity during year.
Relevant Section	D.3
Relevant Equation(s)	6
Source of Data	Model input data requirements, multiple sources
Data Requirements	Model specific
Collection Procedure	To be calculated using a model that meets the requirements of Section D.1
Revision Frequency	Project year (annually)
Comments	

Parameter	$PE_{N2O}(y, i)$
Units	MT CO_2-eq ha^{-1} yr^{-1}
Description	Annual N_2O emissions rate from soils of project parcel i during year y of the project.
Relevant Section	D.3
Relevant Equation(s)	5, 7
Source of Data	Model outputs and Project Proponent records
Data Requirements	$A(i)$, $CE_{N2O}(y, i)$
Collection Procedure	Calculated in equation 7
Revision Frequency	Project year (annually)
Comments	
Parameter	$CE_{N2O}(y, i)$
Units	MT CO_2-eq yr^{-1}
Description	Cumulative Nitrous Oxide emissions from soils of the project parcel i during year y of the project, expressed in CO_2-eq.
Relevant Section	D.3

Relevant Equation(s)	7
Source of Data	Model input data requirements, multiple sources
Data Requirements	Model specific
Collection Procedure	To be calculated using a model that meets the requirements of Section D.1
Revision Frequency	Project year (annually)
Comments	

Parameter	$PE_{fuel}(y, i)$
Units	MT CO_2-eq yr^{-1}
Description	Sum of fuel emissions from transportation to the project parcel and application of the organic material on the land during year y.
Relevant Section	D.3
Relevant Equation(s)	5
Source of Data	Calculated using CDM tool "Project and leakage emissions from road transportation of freight" and CDM tool "Tool to calculate project or leakage CO2 emissions from fossil fuel combustion"
Data Requirements	Quantity and type of fuel consumed and combusted during transportation and application of compost
Collection Procedure	Project Proponent records from transportation and/or compost application receipts
Revision Frequency	Project year when compost is added
Comments	

Parameter	$PE_{compost,CH4}(y, i)$
Units	MT CO_2-eq yr^{-1}
Description	At a year when compost is added, e.g., when $y = 1$, the Methane emissions emitted during composting of the organic material, expressed in CO_2-eq. At all other years, this quantity is to be set to 0. When emission reductions from avoidance of anaerobic emissions are claimed by an entity other than the Project Proponents, this quantity is to be set to 0 at all times to avoid double discounting.
Relevant Section	D.3
Relevant Equation(s)	5
Source of Data	Calculated the most recent emission factor available from the IPCC.
Data Requirements	kg of dry weight organic waste, factor to convert g CH4 to MT CO_2-eq
Collection Procedure	
Revision Frequency	Project year when compost is added
Comments	

Parameter	ER_y
Units	tCO_2-eq yr^{-1}
Description	GHG emissions reductions and/or removals in year y
Relevant Section	D.4
Relevant Equation(s)	8
Source of Data	Calculated in equation 8

Data Requirements	$nrParcels$, $PE(y,i)$, $BE(y,i)$, $CH_4enteric$
Collection Procedure	Based on Project Proponent records, as well as calculations from equations 1 and 5.
Revision Frequency	Project year (annually)
Comments	

Parameter	$nrParcels$
Units	#
Description	Number of project parcels
Relevant Section	D.4
Relevant Equation(s)	8
Source of Data	Project Proponent records
Data Requirements	Parcels participating in the project
Collection Procedure	Counting parcels participating in project
Revision Frequency	For each change in number of project parcel participating- revised before each new crediting period
Comments	

Parameter	$CH_4enteric$
Units	$MTCO_2$-eq yr^{-1}
Description	Enteric emissions associated with an increase in stocking rate over each project parcel.
Relevant Section	D.3, D.4
Relevant Equation(s)	8
Source of Data	Either a value of zero, or the value from cell J13 of the 6.T-XANTE tab of the *ACR Tool for Estimation of Emissions from Livestock Management Projects*, whichever is less.
Data Requirements	Grazing ruminant population, feeding situation (i.e. grazing or not grazing), percentage imported feed vs. grazing, mean daily temperature during winter
Collection Procedure	Project Proponent records
Revision Frequency	Data collected monthly and parameter revised each project year (annually)
Comments	

A.2 Other Project Data Required for Validation

Parameter	$compost$
Units	Multiple
Description	Analysis every time of compost applied
Relevant Section	E
Relevant Equation(s)	
Source of Data	Project Proponent records (from certification or from laboratory test results)
Data Requirements	Carbon concentration, nitrogen concentration, C:N ratio, bulk density, moisture content, pH, phosphorus concentration (optional), source of compost raw

	materials (optional), fate of organic matter under baseline conditions (optional)
Collection Procedure	Project Proponent reports from records
Revision Frequency	Every time compost is applied throughout project
Comments	

Parameter	*soil*
Units	Multiple
Description	Analysis for each stratum representing at least 0-20cm both before and after compost application for baseline and project calculations
Relevant Section	E
Relevant Equation(s)	
Source of Data	Laboratory test results
Data Requirements	Total soil carbon, soil texture, soil bulk density, soil pH
Collection Procedure	Project Proponent collects soil samples submits for analysis
Revision Frequency	Once at the beginning of project and again after the compost application, then at least every 10 years thereafter
Comments	

Parameter	*historical weather*
Units	Multiple (degrees, inches)
Description	Characterizes important weather and climate characteristics for each project
Relevant Section	E
Relevant Equation(s)	
Source of Data	Weather station or other published weather records
Data Requirements	Daily minimum and maximum temperatures, rainfall
Collection Procedure	Project Proponent uses nearest weather station to project or other published weather records (such as Daymet) for use in model
Revision Frequency	Once at the beginning of project to establish a baseline
Comments	

Parameter	*project weather*
Units	Multiple (degrees, inches)
Description	Characterizes important weather and climate characteristics for each project
Relevant Section	E
Relevant Equation(s)	
Source of Data	Weather station or other published weather records used for historical weather
Data Requirements	Daily minimum and maximum temperatures, rainfall
Collection Procedure	Project Proponent uses nearest weather station to project or other published weather records (such as Daymet) for use in model
Revision Frequency	Project year (annually)
Comments	

Parameter	*historical management*
Units	Multiple
Description	Historical grazing practices on Project Proponent’s land

Relevant Section	C
Relevant Equation(s)	
Source of Data	Project Proponent records
Data Requirements	Stocking period (averaged over at least 3 of past 5 years), stocking rate(averaged over at least 3 of past 5 years), incidence of fires
Collection Procedure	Project Proponent records
Revision Frequency	When setting baseline
Comments	

Parameter	*project management*
Units	Multiple
Description	Grazing practices throughout project
Relevant Section	
Relevant Equation(s)	
Source of Data	Project Proponent records
Data Requirements	Project population, stocking period, average stocking rate(averaged over the years), minimum stocking rate, maximum stocking rate, incidence of fires
Collection Procedure	Project Proponent reports from records
Revision Frequency	Project year (annually)
Comments	

Parameter	*Plants and plant communities*
Units	Multiple
Description	Characterizes important plant communities present for each project
Relevant Section	E
Relevant Equation(s)	
Source of Data	Project parcels (Land assessment by a Qualified Expert, consistent with standard NRCS ecological site descriptions)
Data Requirements	Stratification of land, description of plant productivity (species type and forage quality), broad description of plant communities, percentage cover of native plants, indication of any problems with invasive weeds, assessment of fire risk)
Collection Procedure	Land assessment by a Qualified Expert, consistent with standard NRCS ecological site descriptions
Revision Frequency	Once at the beginning of project and at year 2 and year 5 after compost application
Comments	

Parameter	*Compost application*
Units	Multiple
Description	Description of application procedure
Relevant Section	E
Relevant Equation(s)	
Source of Data	
Data Requirements	Application date, machinery used, application method, broadcast rate (tons/ha), rationale for application procedure and reference source (if

	available), receipts of compost purchase, transportation, and application, pictures during application (optional)
Collection Procedure	Collected during compost application
Revision Frequency	Every time compost is applied throughout project
Comments	All data collected as part of monitoring must be archived electronically and be kept at least for two years after the end of the project crediting period.