

Greenhouse Gas Emissions Reductions from Compost Additions to Grazed Grasslands

A methodology developed by Terra Global Capital, with support from the Environmental Defense Fund, Silver Lab at the University of California - Berkeley, and the Marin Carbon Project.

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44 **1 Abbreviations**

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 ₂ O	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

46 **2 Introduction**

47 Adding compost to Grazed Grasslands can be an effective way to increase soil carbon sequestration and
48 avoid emissions related to the anaerobic decomposition of organic waste material in landfills. In addition
49 to climate benefits, adding compost stimulates forage growth, and can improve the quality of soils.¹ A
50 number of recent studies have highlighted that many grasslands are in a state of degradation globally
51 (Bradford and Wilcox, 2007; Baj *et al.*, 2008), though this methodology does not require the grassland to
52 which compost is added to be in a degraded state.

53 This document contains a methodology to account for the carbon sequestration and avoided GHG
54 emissions related to compost additions to Grazed Grasslands, following specifications by the American
55 Carbon Registry (ACR).

56 The current version of this methodology includes only one project activity – compost addition to Grazed
57 Grasslands. Additional project practices and additional organic soil amendment types may be added in
58 future revisions. This approach will allow the experience gained from the first projects to be
59 incorporated in future versions of the methodology.

60 **3 Sources**

61 This methodology relies partially on a number of sources for its carbon accounting:

- 62 • “Organic Waste Composting Project Protocol,” (Version 1.0), available at
63 <http://www.climateactionreserve.org/how/protocols/organic-waste-composting/>, approved for
64 use under the Climate Action Reserve.
- 65 • “Adoption of sustainable agricultural land management (SALM),” available at [http://www.v-c-](http://www.v-c-s.org/sites/v-c-s.org/files/SALM%20Methodolgy%20V5%202011_02%20-14_accepted%20SCS.pdf)
66 [s.org/sites/v-c-s.org/files/SALM%20Methodolgy%20V5%202011_02%20-](http://www.v-c-s.org/sites/v-c-s.org/files/SALM%20Methodolgy%20V5%202011_02%20-14_accepted%20SCS.pdf)
67 [14_accepted%20SCS.pdf](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);
68 developed by the World Bank’s BioCarbon fund
- 69 • The Clean Development Mechanism (CDM) tool “Tool to determine Methane emissions avoided
70 from disposal of dumping waste at a solid waste disposal site,” available at
71 http://cdm.unfccc.int/EB/041/eb41_repan10.pdf
- 72 • The CDM tool “Project and leakage emissions from road transportation of freight,” available at
73 <http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-12-v1.pdf>
- 74 • The CDM tool “Tool to calculate project or leakage CO₂ emissions from fossil fuel combustion,”
75 available at <http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-03-v2.pdf>

76

77

¹ UC Berkeley and the Marin Carbon Project research has found that a single application of compost material is effective in increasing forage production and soil carbon sequestration over three years following application.

78 4 Summary Description of the Methodology

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

- 81 1) **Avoidance of anaerobic decomposition (Optional)** of the organic material used in compost
82 production. Methane (CH₄) emissions that result from anaerobic decomposition of the organic
83 material used in the production of compost under baseline conditions – for example, when the
84 organic matter is buried in landfills – can be avoided by composting² and applying compost on
85 Grazed Grasslands. It is not required in this methodology to include the avoided emissions from
86 preventing the anaerobic decomposition of the organic material used in the production of
87 compost. However, if these avoided emissions are included, evidence must be provided that (1)
88 the avoided emissions have not been claimed under a different Carbon Credit program, such as
89 the Climate Action Reserve’s composting methodology, and that (2) the baseline fate of the
90 organic matter can be demonstrated following the procedures included in Section 8 of this
91 methodology.
- 92 2) **Direct increase in soil organic carbon (SOC) content (Required)** through adding a carbon source
93 from compost. The carbon (C) content of applied compost will lead to a direct increase in soil
94 organic carbon (SOC) content of the Grazed Grasslands where the compost is applied. Even
95 though the carbon added through compost additions will gradually decompose over time, a
96 significant portion will end up in stable carbon pools. The portion of the compost carbon that
97 will remain in the stable pools is likely to be greater than the portion that would be stabilized
98 under baseline conditions. Only the stable carbon pools that are predicted to remain after 40
99 years after compost addition can be counted. These stable soil C pools are conceptually
100 equivalent to the “intermediate” and “passive” C pools defined in recent literature reviews by
101 Trumbore (1997) and Adams et al. (2011). This 40 year period is also similar in duration to the
102 40 year minimum project term used in the approved ACR Forest Carbon Project protocol (ACR
103 2010). As such, the minimum project period for this protocol is 40 years.
- 104 3) **Indirect increase in SOC sequestration (Required)** through enhanced plant growth in Grazed
105 Grasslands amended with compost. The N and P content of the compost, as well as the
106 improved soil water holding capacity of soils amended with compost, lead to an indirect
107 increase in SOC content through an increase in net primary productivity (NPP). The impact of
108 compost on SOC content will depend on the compost’s nutrient content and availability, the soil
109 properties, and grazing management strategies.

110 This methodology requires the use of a model to predict direct and indirect changes in SOC under the
111 baseline and project scenarios. This methodology does not prescribe a specific model. The model can be
112 either a process-based biogeochemical model (PBM) such as the DAYCENT or Denitrification-
113 Decomposition (DNDC) models, or an empirical model such as a Tier-2 Empirical Model that is shown to
114 be effective for the conditions of the Project Parcels (see Section 9.1). It is up to the project proponents

² Whereas composting is mostly an aerobic process that occurs in presence of oxygen, composting may still release a small amount of methane.

115 to demonstrate that the model is sufficiently accurate for the Project Parcels (see section 9.1 for model
116 requirements). Under the baseline scenario, the model is used to simulate any on-going changes to SOC,
117 including potential continuing loss of SOC. Under the project scenario, the model is used to simulate the
118 amount of compost carbon that is stored in recalcitrant SOC pools, and any indirect changes in SOC due
119 to an increase in net primary production and under specific grazing management strategies. Even
120 though empirical models and PBMs have been shown to be highly valid across a wide range of
121 management practices and geographic areas, soil samples and field measurements are required to
122 validate the models for use in specific Project Parcels. As a consequence, this methodology requires
123 monitoring by periodic (10 year) analyses of soil samples for model validation and calibration at
124 different times throughout the project's lifetime.

125 Adding compost to Grazed Grasslands has the potential to increase GHG emissions from secondary
126 sources. Specifically, N₂O emissions from soils are produced due to nitrification and de-nitrification of
127 the available N added through the compost addition (Box 1). These processes further require a carbon
128 source, which is readily available after compost addition. Indirect emissions from nitrate leaching may
129 also occur but GHG emissions resulting from the leached nitrate are expected to be insignificant, at the
130 rate compost is applied in projects under this methodology based on findings reported by DeLonge et al.
131 (2013) for California grasslands. In addition to soil N₂O emissions (from de-nitrification), all emissions
132 from fuel that was used to create, transport, or apply the compost is included in the quantification
133 procedure. Under this methodology, soil N₂O emissions are quantified using an applicable Tier-2
134 Empirical Model, or a calibrated PBM. . The GHG emissions from increased fuel use must be quantified
135 using standard emission factors.

136 Apart from the economic benefit of increased forage production, applying compost to Grazed
137 Grasslands also has many environmental co-benefits, such as improved soil quality, decreased risk of
138 water and wind erosion by increasing soil aggregation, and increased nutrient and water availability for
139 vegetation. Compost can be added to most existing Grazed Grasslands.

140 **Box 1. Further background on N₂O fluxes after compost application**

141 The magnitude of the N₂O fluxes after compost addition may be highly variable and difficult to predict.
142 For example, in an experiment where N₂O fluxes were measured after a one-time compost addition on
143 two sites in California, no significant increases in N₂O fluxes were observed (Ryals and Silver, 2012). In
144 laboratory incubations under controlled conditions, however, a pulse of N₂O emissions was detected in
145 soils after compost addition that was significantly greater than soils to which no compost was added.
146 However, the pulse was short-lived (4 days), and represented only a very small component of the net
147 soil GHG emissions (expressed as CO₂-equivalents) released from the controlled wet up event (Ryals and
148 Silver, 2012). Such conditions represent ideal conditions for N₂O release and are unlikely to be present
149 for a long period of time in the field. High-nitrogen organic materials such as manure or processed
150 manure additions may be more prone to N₂O emissions. Due to the difficulty in predicting N₂O
151 emissions, this methodology allows some flexibility in the approach to quantify N₂O.

152 Production of N₂O is generally greatest under warm and humid conditions and where soil nitrogen
153 concentrations are highest. Therefore, the timing of compost application relative to weather conditions
154 and plant demand is crucial to minimize N₂O emissions. If the Grazed Grassland is dominated by annual
155 plants and the compost application occurs before plant establishment, a significant amount of inorganic
156 N may remain in the soil, resulting in significant N₂O fluxes. However, in a Mediterranean climate, there

157 is an ideal window for applying compost. Specifically, fall applications are preferred, ideally shortly
 158 before first rains and prior to plant establishment in annual-dominated grasslands. Once the soil gets
 159 wet, compost applications may become more logistically challenging due to restricted access to the field
 160 as well as less beneficial, while initial growth of annuals in response to early rains can be expected to
 161 help limit inorganic N losses from the soil. The ideal window for compost addition may be different for
 162 other climates. In this protocol we require following the advice from a Qualified Expert (i.e., a Certified
 163 Rangeland Manager, NRCS Soil Conservationist or Qualified Extension Agent) as to when to apply
 164 compost.

165

166 **5 Definitions**

167 In addition to the definitions set forward by the American Carbon Registry, such as for a GHG Project
 168 Plan, the following definitions apply.

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.
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 <i>et al.</i> (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 10.1).
Native Grassland	Grassland composed primarily of native plants.
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.
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) ³ , 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 ₂ O 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.

169

170 6 Applicability Conditions

- 171 • The Project includes one or more Project Parcels that are Grazed Grasslands at the start of the
172 Project and remain Grazed Grasslands for the duration of the Project (Box 2).

173 After the start of the Project, the Stocking Rate per 10 year crediting period shall remain within pre-
174 determined minimum and maximum Stocking Rate set at plus or minus 3% of the baseline Stocking Rate
175 for each Project Parcel individually. The baseline Stocking Rate and the plus or minus 3% range shall be
176 determined via consultation with a Qualified Expert (see definitions – a Certified Rangeland Manager,
177 NRCS Soil Conservationist or Qualified Extension Agent) and duly justified by the project proponent who
178 must document that they have met the requirement at validation of the GHG Project Plan.⁴ The goal of

³ Livestock 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. 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> and http://en.wikipedia.org/wiki/Livestock_grazing_comparison

⁴ This criterion was added to prevent abusive grazing practices that would be expected to cause reversals of the increased forage production or even further decrease soil organic carbon content. Due to the complexity of rangeland management, this methodology refrains from prescribing a maximal stocking rate. It is believed that

179 the requirement for project proponents to maintain Stocking Rates within the plus or minus 3% of
180 baseline range throughout the 10 year crediting period is to maintain yield neutrality in terms of cattle
181 produced and rangeland forage quality is maintained. The minimum Stocking Rate shall be set to ensure
182 that plant community species composition does not change toward a less desirable plant community in
183 response to soil quality improvement following compost application. Maximum Stocking Rate shall be
184 set so that the rangeland utilization remains sustainable, taking into account an increase in forage
185 production and any changes in the percentage of grazer feed coming from purchased sources after the
186 start of the crediting period.⁵ This range of plus or minus 3% of the baseline Stocking Rate is consistent
187 with the project output limits for project activities used in the ACR Grazing Land and Livestock
188 Management Greenhouse Gas Mitigation Methodology⁶. The baseline Stocking Rate and the plus or
189 minus 3% range must be re-evaluated two and five years after each compost addition and adjusted as
190 necessary in dialogue with a Qualified Expert.

- 191 • Any soils that are regularly flooded (i.e. more than 2 months per year), shall be excluded from
192 the Project Parcels.⁷ At the start of the project the Certified Rangeland Manager, NRCS Soil
193 Conservationist or Qualified Extension Agent must identify any land within the parcel that ought
194 to be excluded due to a high likelihood of annual flooding. These areas can be detected by
195 observing the topographic position in the landscape as well as clear shifts in vegetation and soil
196 redox features (e.g. gleying). These areas must be excluded from the Project Parcel at the
197 beginning of the crediting period.
- 198 • The compost added to the Project Parcel must be within the following specifications:
 - 199 ○ The final end-product after composting must have a nitrogen concentration of less than
200 3%⁸ on a dry-weight basis.
 - 201 ○ Best Management Practices put forward by state agencies have been followed in
202 making the compost free of any seeds or propagules capable of germination or growth.
 - 203 ○ The heavy metal and contaminant content of composts shall not exceed limits of the US
204 EPA under 40 CFR 503⁹.

rangeland experts are best placed to determine the maximum stocking rates. The proposed maximum stocking rate may be verified by an independent rangeland expert hired by the third-party auditor.

⁵ This approach is fully compatible with a rotational grazing strategy.

⁶ The ACR “Grazing Land and Livestock Management Greenhouse Gas Mitigation Methodology” can be found online at <http://americancarbonregistry.org/carbon-accounting/grazing-land-and-livestock-management-methodology>

⁷ The no-flood requirement is added to prevent the inclusion of land areas where a significant amount of CH₄ is likely to be emitted from soils in the project area; the accounting for methanogenesis is not included.

⁸ This would prevent materials that more closely resemble synthetic fertilizers from being used as an amendment.

⁹ 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.

- 205 ○ The compost must be produced in accordance with Chapter 5 of EPA Part 503 Biosolids
206 Rule.¹⁰
- 207 ○ Waste Material containing food waste or manure must be either (1) mixed and
208 incorporated into the composting process within 24 hours of delivery of the waste to
209 the composting facility, (2) covered or blended with a layer of high-carbon materials
210 such as wood chips or finished compost within 24 hours of delivery, and mixed and
211 incorporated into the composting process no more than 72 hours after delivery, (3)
212 placed in a controlled environment within 24 hours of delivery, or (4) handled using any
213 other alternative Best Management Practices to avoid anaerobic decomposition after
214 delivery and before incorporation into the composting process of the source material.¹¹
215 Compost material that was produced consistently with the standards put forward by the
216 California Department of Resources Recycling and Recovery is automatically approved.

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

218 Compost applications may lead to changes in the plant community (either positive or negative) due to
219 impacts of compost on nutrient concentrations and hydrology of treated soils (Bremer, 2009). The
220 protocol does not support application of compost to intact, healthy native plant communities. Species
221 composition may also change where grazing is discontinued after compost addition (Lowe *et al.*, 2002;
222 Berg, 1995). To reduce this risk, grazing must have been present in the past and must continue at rates
223 determined by qualified range professional during the project period.

224 **7 Project Boundary**

225 **7.1 Geographic Boundary**

226 **7.1.1 Project Parcel**

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

¹⁰ Chapter 5 focuses on Pathogen and Vector Attraction Reduction Requirements. On page 116, it is explained that “*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

¹¹ 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.

231 New Project Parcels may be added to an existing Project after the start of the crediting period as long as
232 all the applicability criteria are met for each individual Project Parcel.

233 7.1.2 Composting Facility (Optional)

234 In case GHG emission reductions from composting source material and avoidance of anaerobic
235 decomposition are claimed as Emission Reduction Tons (ERTs) under this methodology, the composting
236 facility shall be included in the geographic boundary. In this case, the project proponent(s) shall include
237 a formal affidavit indicating that no other party than the project proponent(s) has claimed the ERTs from
238 composting source material and avoidance of anaerobic decomposition under any compliance or
239 voluntary carbon registry. This affidavit would be issued by the project proponent(s) but will also include
240 a signature from the owner of the composting facility attesting that the facility is not claiming carbon
241 credits.

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

244 7.1.3 Stratification

245 This methodology encourages combining Project Parcels spread over a large geographic region within
246 one Project to reduce costs. However, environmental, soil, and management conditions may not be
247 homogeneous across a large geographic region. Non-homogeneous conditions may affect the validity of
248 baseline calculations and additionality checks. Therefore, heterogeneous Project Parcels shall be
249 subdivided into smaller units or strata that are considered homogeneous for the purpose of carbon
250 accounting. A different set of input parameters to the model(s) for carbon accounting selected in
251 Section 9.1 shall be prepared for each different stratum. Parameters that shall be considered to stratify
252 the Project Parcels are:

- 253 • Historical rangeland management practices
- 254 • Future rangeland management practices after the start of the Project
- 255 • Different soil types, especially special status soils (e.g., serpentine soils, histosols, etc.)
- 256 • Ecological characteristics (soil texture, aspect, slope, hydrology, climate, plant communities)
- 257 • Degradation status (initial soil C content, soil bulk density)
- 258 • Differences in legally binding requirements affecting management of the Project (e.g., easement
259 status of land, ownership)

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

264 7.2 Greenhouse Gas Boundary

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

266 Baseline scenario

- 267 • Emissions resulting from anaerobic decay of organic waste at a final disposal/treatment system
268 (e.g., landfill or manure management system). This source is optional and may be omitted; doing
269 so is conservative. If the composting facility will claim ERTs from avoiding emissions from
270 anaerobic decay of organic waste, this source may not be included in the GHG accounting for
271 the project. If this source of ERTs is claimed by the Project, the project proponent(s) shall
272 include a formal affidavit indicating that no other party than the project proponent(s) have
273 claimed the ERTs from composting source material and avoidance of anaerobic decomposition
274 under any compliance or voluntary carbon registry.
- 275 • Background losses of SOC, potentially related to continuous loss of soil organic carbon¹² of the
276 Grassland as predicted through modeling.

277 Project scenario

- 278 • Emissions resulting from the composting process, including active composting and curing of
279 compost at project facilities. To avoid double deductions, this source of emissions shall be
280 omitted in case the composting facility claims ERTs for avoiding emissions from anaerobic decay
281 of organic waste.
- 282 • Fossil fuel emissions from the transport of the finished compost to the Project Parcels.
283 • Emissions related to the land application of compost.
284 • Emissions of CO₂ and N₂O related to the decomposition of compost after application.
285 • Sequestration of carbon related to the increase in plant productivity on the grassland.
286 • Sequestration related to the transfer of compost into recalcitrant SOC pools.¹³
287 • Avoided emissions related to the lack of transportation associated with importation of forage.

288 Fossil fuel emissions from transport of organic waste materials to final disposal/treatment system (e.g.
289 garbage trucks, hauling trucks, etc.) under baseline conditions are assumed to be equal to the fossil fuel
290 emissions from transporting waste materials to the compost facility in the project case¹⁴, and are
291 therefore not included in the GHG accounting (Brown *et al.*, 2009).

292 The GHG emissions from storage of waste in the composting facility are assumed to be insignificant
293 when the applicability conditions laid out in Section 6 are followed.

¹² 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).

¹³ Only carbon stored in recalcitrant soil pools is considered sequestered

¹⁴ 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.

294 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 ₂ O	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 ERTs for avoiding emissions from anaerobic decay of organic waste, this source of emissions shall be omitted to avoid double deductions.
		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 ERTs for avoiding emissions from anaerobic decay of organic waste, this source of emissions shall be omitted to avoid double deductions.
		N ₂ O	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 ERTs for avoiding emissions from anaerobic decay of organic waste, this source of emissions shall be omitted to avoid double deductions.

	Fossil fuel emissions from transport of organic waste to landfill	CO ₂	No	Assumed to be similar to fossil fuel emissions from transport of organic waste to composting facility.
Project	Project Parcels soil	CO ₂	Yes	Emissions related to the further decomposition of the compost added as well as additional heterotrophic soil respiration resulting from compost additions.
		N ₂ O	Yes	Nitrous oxide emissions after compost additions are likely small due to the complex nature of compost but are included in the accounting to remain conservative.
		CH ₄	No	Non-flooded soils can be a source or sink of Methane but fluxes are negligible
	Ruminants	CH ₄	No	Enteric fermentation emissions from increased or decreased ruminant Stocking Rates are potentially significant.
	Emissions due to leaching	N ₂ O	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 to the compost facility	CO ₂	No	Assumed to be similar to fossil fuel emissions from transport 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.
Emissions due to composting	CO ₂	Yes/No	Composting is a partial decomposition process in which carbon dioxide is released. To avoid double deductions, this source of emissions shall be omitted in case the composting facility claims ERTs for avoiding emissions from anaerobic decay of organic waste.
	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 ERTs for avoiding emissions from anaerobic decay of organic waste.
	N ₂ O	No	Nitrous oxide emissions during composting are negligible

295

296 **Table 2. Overview of included pools**

Pool	Included?	Rationale
Above-ground non-tree biomass	Yes	A major pool affected by project activities. An increase in forage production is expected as a result of compost additions. Note that the amount of standing biomass at the end of the season will depend on Stocking Rate and might not change after compost addition.
Below-ground non-tree biomass	Yes	A major pool affected by project activities. Increased root production is expected as a result of the compost addition.
Litter	Yes	Major pool affected by project activities: the added compost is deposited on the surface and will therefore be part of the litter pool immediately after application.
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 is expected to increase the soil organic matter content.
Wood Products	No	Not a major pool affected by project activities.

297 **7.3 Temporal Boundary**

298 The project start date shall coincide with the first compost application event. The minimum project term
 299 will be 40 years due to the fact that the ERTs claimed as a result of the compost additions to rangeland
 300 soils are calculated based on the stability of the “intermediate” and “passive” C pools being greater than
 301 40 years (see Sections 4 and 9.2). The crediting period is defined by ACR Standard Version 3.0 as the
 302 finite length of time for which a GHG Project Plan is valid, and during which a project can generate
 303 offsets against its baseline scenario¹⁵. The crediting period for each project will be 10 years and
 304 validation of the GHG Project Plan will occur once per crediting period. Crediting periods are limited in
 305 order to require project proponents to reconfirm at set intervals that the baseline scenario remains
 306 realistic, credible, additional, and that the current best GHG accounting practice is being used¹⁶. Since
 307 ACR places no limit on the number of crediting period renewals, the project proponent may renew the
 308 crediting period in 10 year increments thereafter, provided that the project still meets the protocol

¹⁵ The ACR Standard Version 3.0 can be found online at <http://americancarbonregistry.org/carbon-accounting/acr-standard-v3.0>

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

314 **8 Procedure for Determining the Baseline Scenario and Demonstrating** 315 **Additionality**

316 Emission reductions from avoidance of anaerobic decomposition have very different additionality
317 considerations than emission reductions from direct and indirect increases in SOC. Project proponents
318 who are not claiming any ERTs from avoidance of anaerobic decomposition do not have to consider the
319 additionality requirements related to this source of emission reductions, covered in Section 8.1. Since all
320 projects using this methodology will add compost to Grazed Grasslands, all project proponents shall
321 follow the additionality requirements related to direct and indirect increases in SOC, covered in Section
322 8.2.

323 **8.1 Additionality of Emission Reductions from Avoidance of Anaerobic Decomposition**

324 Project proponents shall use ACR's three-prong approach¹⁷ demonstrate additionality. Specifically, in
325 cases where ERTs from landfill diversion are obtained, it must be demonstrated that the source material
326 used for composting was diverted from a landfill or anaerobic manure storage by at least one of the
327 approaches detailed below. Valid evidence includes economic analyses, reports, peer-reviewed
328 literature, industry group publications, surveys, etc. Note that examples of the application of these
329 approaches are provided in Section 8.1.2

- 330 • Evidence is provided that the specific source of the waste material used for composting (e.g.,
331 the specific waste collector) has deposited an average of 75% of the waste material in a landfill
332 or storage under anaerobic conditions (in the case of manure) for a period of five years prior to
333 the project's starting date.
- 334 • Statistics are provided that indicate that more than 90% of the waste material used for
335 composting is landfilled averaged for a period of five years prior to the Project's starting date
336 within the state in which the Project is located.
- 337 • Within the USA, statistics are provided that indicate that more than 95% of the waste material
338 used for composting is landfilled averaged for a period of five years prior to the Project's
339 starting date.

¹⁷ The three-prong test is explained in the ACR Standard. In short, ACR uses an approach that combines three tests that help determine whether realizing GHG emissions reductions/removals was a motivation, even if one among many, for implementing the project activity. The three tests are based on Regulatory Surplus, Common Practice, and Implementation Barriers.

340 Once ACR's three-prong test is passed, the baseline management is set as a continuation of the
341 historical management. The historical management is defined by acquiring the following three
342 parameters for a period of at least 3 years¹⁸ before the start of the Project:

- 343 • Stocking Rates
- 344 • Stocking periods
- 345 • Incidence of fires

346 The historical grazing management shall be duly described. These management parameters and other
347 site-specific parameters that are required to define the baseline are included in the list of parameters
348 available at model validation (Section 10.1).

349 8.1.1 Co-composting

350 Often, multiple waste sources are composted together to get an optimal composting C-to-N ratio and
351 increase the waste streams that can be processed. This is referred to as co-composting. In case one of
352 the materials used during co-composting is non-additional, the proportion of the waste that is additional
353 shall be recorded and used in subsequent calculations in Section 8.2 as parameter $f_{diverted}$. In case all
354 the waste material is additional, $f_{diverted}$ shall be set to 1. The $f_{diverted}$ factor is used in subsequent
355 calculations to discount any GHG benefits so that only additional benefits are counted.

356 8.1.2 Examples of determining additionality through diversion of waste materials

- 357 • Studies by Biocycle Magazine, referenced in a report published by the EPA in 2008¹⁹, estimate
358 that, at a national level, 97.4% of solid food waste (e.g., milk solids, condemned animal
359 carcasses, meat scraps, and pomace wastes from wineries) were landfilled in 2007. Therefore,
360 compost made from solid food waste is additional without the need for any further evidence.
- 361 • The same report published by the EPA in 2008 estimated that 35.9% of the total quantity of yard
362 waste was landfilled. Therefore, a project developer must demonstrate that the specific source
363 of the waste material, i.e., the waste collector of a specific municipality, has landfilled the yard
364 waste for a period of five years prior to the Project's starting date.
- 365 • California generates 750,000 dry tons of biosolids, the by-product of channeling human waste
366 through treatment plants and collection systems (California Association of Sanitation Agencies).
367 In total, 54% is land applied and 16% is composted according to statistics from CalRecycle,
368 available at <http://www.calrecycle.ca.gov/organics/biosolids/#Composting>. Therefore, a project
369 developer must demonstrate that the specific source of the biosolids, i.e., the biosolids of a
370 specific municipality, have been landfilled in the past.

¹⁸ 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.

¹⁹ 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>

- The biosolids from sources that are already land-applied (currently 54 %) are 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.

8.2 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.

9 Quantification of GHG Emission Reductions and Removals

9.1 Requirements for Models used for Quantifying GHG emissions and removals

This methodology does not prescribe a model to quantify changes in SOC and soil N₂O 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 N₂O emissions. The remainder of this section contains general requirements related to the use of Tier-2 Empirical Models, or 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 use 90% confidence. The two sources of uncertainty, structural uncertainty and input uncertainty, shall simply be summed to calculate the total uncertainty. For the N₂O 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]

399

400 9.1.1 Tier-2 Empirical Models

401 Project proponents may develop Tier-2 Empirical Models, which may be used once they appear in the
402 peer-reviewed scientific literature. Project Proponents shall justify in the GHG Project Plan that the
403 sampling locations to create the regionally applicable Tier-2 Empirical Models are representative for the
404 Project. Data from at least five sites across two years must be used to calculate the Tier-2 Empirical
405 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.

406 9.1.2 Process-based Biogeochemical Models (PBMs)

407 PBMs such as Century, Daycent²⁰, EPIC, ROTH-C, or DNDC may be used on the condition that they are
408 validated for the conditions of the Project Parcels and for the specific variable that is under
409 consideration (i.e., annual change in SOC content, SOC content, or annual N₂O emissions). The PBM
410 must be peer reviewed in at least three scientific publications. The PBMs indicated above meet the
411 requirement on the scientific publications. In addition, an objective and unambiguous operating
412 procedure to parameterize and run the PBMs must be developed by the project proponents. This
413 procedure document must spell out how every input parameter shall be set. The applicability of the
414 selected model is dependent on the soil type(s), climate, and broad management of the area in which
415 the model is applied. Therefore, it is required to (1) validate the model for the conditions of the Project
416 Parcels, and (2) specify the conditions under which the model's operating procedures remain valid. The
417 validation of a model shall be conducted by comparing field measurements to model predictions. Once
418 model validation has been completed, it does not need to be repeated.

419 With relation to the model validation for the conditions of the Project Parcels and specific variables
420 under consideration, the following conditions must be met:

²⁰ 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 N₂O and CH₄ emissions whereas Century cannot.

- 421 1) At least 10 field measurements of the variable in question are available within 50 km of the
422 Project Parcels²¹. These measurements must be clearly representative of the baseline conditions
423 present in the Project Parcels, with respect to landscape, soil types, climate, and broad land
424 management. In addition, the 10 measurements must come from at least 2 different years, and
425 preferably from as many years as possible to address temporal variability.
426 2) The slope of the relation between modeled and measured values shall be between 0.9 and 1.1
427 as tested using two one-sided t-tests using a significance of 90%.

428

429

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 CO₂-equivalents, as is commonly done in GHG accounting methodologies. This uncertainty shall be noted and subtracted from the final ERTs, as explained in Section 9.4. An uncertainty for N₂O 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 N₂O emissions, except for a multiplication with 310 x 44 / 7, to account for the radiative forcing and molecular weight of N₂O.

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.

430

431 9.2 Baseline Emissions

432 9.2.1 *General Equation*

433 The emissions of the waste material when deposited in a landfill must be calculated for each project
434 parcel separately using the following equations:

435

²¹ The same field measurements may be used for Project Parcels that are in close vicinity to each other and that are submitted within one GHG Project Plan.

436 [EQ 1]

$$BE(y, i) = BE_{landfill}(y, i) + BE_{\Delta SOC}(y, i) + BE_{N_2O}(y, i)$$

437 Sub-equations for Components:

438 [EQ 2]

$$BE_{landfill}(y, i) = BE_{landfill,CH_4} - \left(\frac{\sum_{j=1}^j W_j \cdot DOC_j \cdot DOC_f \cdot 44}{40 \cdot 12} \right)$$

439 [EQ 3]

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

440 [EQ 4]

$$BE_{N_2O}(y, i) = A(i) \cdot CE_{N_2O}(y, i)$$

441 Where:

- $BE(y, i)$ = The total sum of the baseline emissions associated with project parcel i during year y . See EQ 1 above. [MT CO₂-eq yr⁻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 CO₂-eq yr⁻¹]
- $BE_{landfill,CH_4}(y, i)$ = 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 CO₂-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 degradable organic carbon (by weight) in the waste type j . 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 can decompose. 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 9.1. 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 9.1. [MT C ha ⁻¹ yr ⁻¹]
$BE_{N_2O}(y, i)$	=	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 9.1. See EQ 4 above. [MT CO ₂ -eq yr ⁻¹]
$CE_{N_2O}(y, i)$	=	Annual N ₂ O 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 9.1. [MT CO ₂ -eq ha ⁻¹ yr ⁻¹]

442 Note that the “44/12” factor converts a mass of carbon into a mass of Carbon Dioxide. In addition, the
 443 quantity $W_j \cdot DOC_j \cdot DOC_f$ represents the cumulative mass of carbon that is decomposed after 40 years
 444 in a landfill for waste material. Therefore, $\frac{44 \sum_{i=1}^j W_j \cdot DOC_j \cdot DOC_f}{12 \cdot 40}$ represents the annual CO₂ emissions from
 445 decomposition of the waste material in the landfill under the baseline scenario.

446 9.2.2 Quantification Procedure

447 The value $BE_{landfill, CH_4}(y, i)$ shall be calculated as the quantity $BE_{CH_4, SWDS, y}$ using the CDM tool “Tool
 448 to determine Methane emissions avoided from disposal of dumping waste at a solid waste disposal
 449 site.” The quantities W_j , DOC_j , and DOC_f shall be set according to this CDM tool. Finally, the quantity
 450 $BE_{\Delta SOC}(y, i)$ shall be calculated using a model that meets the requirements of Section 9.1.

451 9.3 Project Emissions

452 9.3.1 General Equation

453 [EQ 5]

$$PE(y, i) = PE_{\Delta SOC}(y, i) + PE_{N_2O}(y, i) + PE_{fuel}(y, i) + PE_{compost, CH_4}(y, i)$$

454 **Sub-Equations for Components**

455 [EQ 6]

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

456 [EQ 7]

$$PE_{N_2O}(y, i) = A(i) \cdot CE_{N_2O}(y, i)$$

457

458 Where:

- $PE(y, i)$ = The total sum of the project emissions during year y . [MT CO₂-eq yr⁻¹]
- $PE_{\Delta SOC}(y, i)$ = Annual CO₂ 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 9.1. 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 CO₂. See EQ 6 above. [MT CO₂-eq yr⁻¹]
- $A(i)$ = 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 9.1 [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 9.1. [MT C ha⁻¹ yr⁻¹]
- $\frac{44}{12}$ = Factor to convert the mass of C to CO₂.
- $CE_{N_2O}(y, i)$ = Cumulative Nitrous Oxide emissions from soils of the project parcel i during year y of the project, expressed in CO₂-eq. To be calculated using a model that meets the requirements of Section 9.1. See EQ 7 above. [MT CO₂-eq yr⁻¹]
- $ER_{N_2O}(y, i)$ = Annual N₂O 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 9.1. [MT CO₂-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 CO₂-

eq yr⁻¹]

$PE_{compost,CH_4}(y, i)$ = At a year when compost is added, e.g., when $y = 1$, the Methane emissions emitted during composting of the organic material, expressed in CO₂-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 CO₂-eq yr⁻¹]

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

462 The emissions of the waste material when deposited in a landfill must be calculated for each project
463 parcel separately using the following equations:

464 9.3.2 Quantification Procedure

465 The quantities $\Delta SOC_d(40)$, $\Delta SOC_i(y)$, and $PE_{N_2O}(i, y)$ shall be calculated using a Tier-2 Empirical
466 Model, or a PBM. If a PBM is used that is based on conceptual C-pools, only pools that have a turnover
467 time of greater than 2 years shall be counted towards $\Delta SOC_d(40)$ and $\Delta SOC_i(y)$. This provision is
468 included to avoid incorporating carbon sources that are readily decomposable as carbon sequestration.
469 $\Delta SOC_d(40)$ and $\Delta SOC_i(y)$ must be *reduced* by an appropriate discounting factor, while $PE_{N_2O}(i, y)$ must
470 be increased by an appropriate discounting factor, as specified in Section 9.1.

471 $PE_{fuel}(i, y)$ is the sum of the emissions from fuel use from transportation and the fuel use from
472 application of the compost. The fuel use from transportation of the compost shall be calculated using
473 the CDM tool "Project and leakage emissions from road transportation of freight." The fuel use from
474 application of the compost shall be calculated using the CDM tool "Tool to calculate project or leakage
475 CO₂ emissions from fossil fuel combustion."

476 $PE_{compost,CH_4}(i)$ shall be calculated using an appropriate emission factor available from the EPA or the
477 IPCC.

478 9.4 Summary of GHG Emission Reduction and/or Removals

479 [EQ 8]

$$ER_y = \sum_{i=1}^{nrParcels} f_{diverted}(PE(y, i) - BE(y, i))$$

480 Where:

ER_y = GHG emissions reductions and/or removals in year y [tCO₂-eq yr⁻¹]

$nrParcels$	=	Number of individual Project Parcels
$f_{diverted}$	=	The percentage of the waste source that is additional. See Section 8.1.1.
$PE(y, i)$	=	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]

481 9.5 Leakage

482 Available field research suggests that the addition of compost to grasslands will generally increase soil
 483 carbon and the production of forage for livestock. As such, it is highly unlikely that project activities will
 484 lead directly to emissions leakage via reduced Stocking Rates on the parcel and increased grazing
 485 intensity beyond the project boundaries. The chance of leakage is further prevented by applicability
 486 condition 2 in Section 6, which stipulates that all Project Parcels must remain grazed for the duration of
 487 the project at between plus or minus 3% of the baseline Stocking Rate averaged over the crediting
 488 period. Furthermore, the proponent is also required to monitor and document Stocking Rates each
 489 season of the project to ensure that there are no significant changes in Stocking Rates. If Stocking Rates
 490 stay within this plus or minus 3% range around the baseline then it is reasonable to assume that little or
 491 no leakage has occurred.

492 If for any reason average Stocking Rates in a Project Parcel for a given 10 year crediting period fall below
 493 97% or above 103% of the baseline then the proponent will not be permitted to claim ERTs on the parcel
 494 in question during that crediting period. The proponent will also be required to provide information and
 495 a rationale justifying why Stocking Rates fell outside the acceptable range, which will help the verifier
 496 determine if the changes were due to project activities or circumstances unrelated to the project
 497 activities. Examples of common unrelated circumstances that may cause a proponent to temporarily
 498 reduce Stocking Rates are the occurrence of multi-year drought or unfavorable market conditions for
 499 the livestock industry. Since these non-project related circumstances are outside of the proponents'
 500 control, they will be able to resume claiming ERTs in subsequent periods if and when Stocking rates
 501 return to baseline levels.

502 10 Monitoring

503 10.1 Data and Parameters Available at Validation

504 Various data elements related to compost, soil, weather, and management must be available at model
 505 validation. The specific data elements required are detailed below.

- 506 • **Compost.** The following data must be available for each batch of compost. Unless sound data
 507 for these parameters are available (e.g., as a result from a certification), the compost must
 508 undergo laboratory tests.
 - 509 ○ The **Carbon Concentration** is required to convert mass of dry compost to mass of
 510 carbon added, which is a property that is required by a model.
 - 511 ○ The **Nitrogen Concentration** is required to convert mass of dry compost to mass of
 512 nitrogen added, which is needed to verify the applicability conditions and may also be
 513 required for the model used.

- 514 ○ It is advised, but not required, to include the **phosphorus content** in the elemental
- 515 analysis, as this may improve the models' ability to simulate changes in SOC related to
- 516 compost addition.
- 517 ○ The **Bulk Density** is required to convert a volume of compost, a very common unit used
- 518 by compost facilities, spreaders, and transporters, into a mass of compost.
- 519 ○ The **moisture content** is required to convert a mass of moist compost into dry compost.

520 In addition, the following information shall be obtained if available:

- 521 ○ Source of the compost raw materials
- 522 ○ Fate of the organic matter under baseline conditions
- 523 ● **Soil.** At least three soil samples shall be taken within each stratum representing at least 0-20 cm.
- 524 If the relative standard error among the three samples is greater than 20%, more samples shall
- 525 be taken until the relative standard error is less than 20%. Project developers may choose to
- 526 take more and deeper samples than this minimum requirement. Samples shall not be
- 527 composited. The following measurements shall be conducted on the soil samples:
 - 528 ○ Soil carbon
 - 529 ○ Soil texture
 - 530 ○ Soil bulk density

531 Note that the project developer is allowed to measure the soil carbon at the start of the project

532 *after* compost application on reference locations within the Project Parcels that did not receive

533 the compost application. The latter is feasible when reference locations are shielded from

534 compost application by putting a tarp at that location and removing the compost that is

535 deposited on the tarp before soil carbon analysis.

- 536 ● **Historical weather.** Daily minimum and maximum temperatures and rainfall shall be obtained
- 537 for a period of ten years before the start of the Project. Historical weather data must come from
- 538 the nearest weather station or other published weather records (such as Daymet).
- 539 ● **Historical management.** The following parameters shall be provided for each stratum for a
- 540 period of at least 5 years before the start of the project. Additional years of data are highly
- 541 recommended if significant changes in land cover or management are known to have occurred
 - 542 ○ Stocking rates
 - 543 ○ Stocking periods
 - 544 ○ Incidence of fires
- 545 ● **Plants and plant communities.** A land assessment by a Qualified Expert must be provided that
- 546 includes a stratification of the land and a description of plant productivity (which is inclusive of
- 547 species type and forage quality) into three groups: "poor", "medium", or "high". Values of net
- 548 primary productivity are helpful but not required. The land assessment report shall contain a
- 549 broad description of the plant communities, percentage cover of natives as well as any problems
- 550 with invasive weeds before the start of the project. Finally, the land assessment report shall
- 551 contain an assessment of the fire risk.

552 In addition to the parameters described above, various additional soil and site parameters may be

553 needed to parameterize the model runs. The onus is on the project developer to demonstrate that a

554 model was used and parameterized correctly.

555 10.2 Data and Parameters Recorded during Compost Application

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

- 557 ● Application date

- 558 • Machinery used
- 559 • Application method
- 560 • Broadcast rate (tons/ha)

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

565 10.3 Data and Parameters Monitored after Compost Application

566 Soil carbon shall be measured at the start of the project and at least every 10 years thereafter. In
567 addition, an update of the land assessment report by a Qualified Expert shall be conducted 2 and 5 years
568 after compost application.

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

573 10.4 Updating Models and Model Structural Uncertainty Deduction

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

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

586 11 Permanence

587 Projects must be consistent with the ACR Standards for permanence which requires proponents to sign
588 ACR's risk mitigation agreement²². This risk mitigation agreement legally requires the project
589 proponents to conduct a risk assessment using the latest ACR-approved Non-Permanence Risk Analysis

²² The ARC Standard Version 3.0 can be found online at <http://americancarbonregistry.org/carbon-accounting/acr-standard-v3.0>

590 and Buffer Determination tool²³. The result of this assessment is an overall risk category for the project,
591 translating into a percentage or number of ERTs that the project proponent must deposit, at each new
592 ERT issuance, into a shared non-permanence buffer pool managed by ACR. Alternatively, the proponent
593 may also meet its legal obligations by providing evidence of sufficient insurance coverage with an ACR-
594 approved insurance product. Reversals need only be fully compensated when they occur during the
595 period in which monitoring is required (i.e. during the minimum project term).
596

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

608 Any conversion of a project parcel to any other land use than Grazed Grassland, such as agriculture or
609 development, will immediately exclude this parcel from generating future ERTs. Unless the soil carbon
610 loss due to the conversion on this Project Parcel is duly replaced by acquiring ERTs from this or other
611 projects and project types, all ERTs from previously stored soil carbon shall be considered a reversal of
612 previously credited ERTs. In addition to the aforementioned risk mitigation mechanisms discussed
613 above, the project proponent may replace the reversed ERTs with ERTs issued from other project
614 parcels within the same project within two years of the date of the conversion. Note that even after
615 replacing the ERTs lost to conversion, the project parcel that was converted must be permanently
616 excluded from issuing ERTs. All other Project Parcels within the Project are not affected by one project
617 parcel being converted to another land-use. In case only part of a parcel was converted to another land
618 use, it is allowed to pro-rate the reversed ERTs or re-purchase ERTs based on the relative proportion of
619 the conversion within the parcel. Land use conversion shall be considered an intentional reversal
620 according to terms of the risk mitigation agreement.

621 In the unlikely case that a tillage event occurs on the Project Parcel without a conversion of the
622 grassland to agricultural or any other land use, all soil carbon ERTs previously issued from this Project
623 Parcel will be considered to have been reversed unless the carbon losses resulting from the tillage event
624 on the Project Parcel are duly accounted for and compensated by retiring existing ERTs from the current
625 or other projects and project types. Similarly to land conversions, this carbon loss shall be verified in a
626 monitoring report and must be verified by a VVB. In addition, unless such a true-up occurs, the project

²³ 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>

627 parcel shall be permanently excluded from issuing ERTs. Tillage shall be considered an intentional
628 reversal according to terms of the risk mitigation agreement.

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