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VM0022

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Sectoral Scope 14

Quantifying N_2O Emissions Reductions in Agricultural Crops through Nitrogen Fertilizer Rate Reduction

Methodology prepared by:

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1 SOURCES

VCS Standard v3.3

VCS AFOLU Requirements v3.3

VCS Program Guide v3.4

2006 IPCC Guidelines for National Greenhouse Gas Inventories

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology quantifies emissions reductions of nitrous oxide (N_2O) from agriculture in the United States (US), as brought about by reductions in the rate of nitrogen (N) fertilizer (synthetic and organic) applied to cropland. The methodology encourages the application of economically optimum N fertilizer rates that do not harm productivity, and requires the use of verifiable best management practices for N timing, placement, and type. Depending on the US state where a project is implemented, the methodology uses either a generally accepted IPCC Tier 1 emission factor or an empirically derived Tier 2 regional emission factor (applicable in the 12 state North Central Region) to aid in calculating N_2O emissions reductions. The approach is straightforward and transparent and is a practical solution to help reduce N_2O emissions and other reactive N pollutants from agriculture. The field research that underpins the methodology is publicly available in the peer-reviewed literature.

Nitrous oxide production in agricultural soil occurs predominantly through the microbial transformations of inorganic N (Robertson and Groffman 2007). The potential to produce and emit N_2O increases with the increasing availability of N (Bouwman et al. 1993). Due to the strong influence of available soil N on N_2O emissions, some emissions of N_2O are an unavoidable consequence of maintaining highly productive cropland (Mosier 2002). However, any activity or process that acts to keep available soil N low will lead to lower N_2O emissions. Anthropogenic activities that lower the input of N into cropland agriculture help to reduce emissions of N_2O (Robertson and Vitousek 2009).

To date the vast majority of evidence supports N input as the most robust and reliable default proxy for calculating N_2O emissions. It is consistent and straightforward to quantify as a metric and its use is substantiated by the IPCC, which uses annual N rate as the default method for calculating N_2O emissions from managed land in national greenhouse gas inventories. Moreover, its alteration is readily accessible to management intervention.

Table 1: Additionality and Crediting Baseline Methods

Additionality	Performance Method
Crediting Baseline	Performance Method

3 DEFINITIONS

Synthetic nitrogen fertilizer: Any synthetic fertilizer (solid, liquid, gaseous) containing nitrogen (N). This may be a single nutrient fertilizer product (only including N), or any other synthetic fertilizer containing N, such as multi–nutrient fertilizers (e.g., N–P–K fertilizers) and ‘enhanced–efficiency’ N fertilizers (e.g., slow release, controlled release and stabilized N fertilizers).

Organic nitrogen fertilizer: Any organic material containing N, including animal manure, compost and sewage sludge.

Direct N_2O emissions: Those emitted directly from the site to which fertilizer N has been applied.

Indirect N_2O emissions: Those emitted beyond the site to which fertilizer N has been applied, but as a result of the fertilizer N applied at the site

North Central Region: The North Central Region (NCR) of the USA encompasses the 12 Midwestern states of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin.

4 APPLICABILITY CONDITIONS

4.1 The methodology applies to Agricultural Land Management (ALM) project activities) that reduce net nitrous oxide (N_2O) emissions from agricultural cropping systems by reducing the nitrogen (N) fertilizer application rate compared to the business as usual (BAU) scenario.

4.2 Implementation of project activities under this methodology must not lead to violation of any applicable law even if the law is not enforced.

4.3 Projects must not be at sites that have not be cleared of native ecosystems and where eligible cropping systems have been grown for at least ten years prior to project implementation. Eligible cropping systems are defined in the applicability condition 4.8.

4.4 The following conditions with respect to fertilizer nitrogen sources must be met:

Sources of fertilizer N eligible under this methodology must be a sub–set of those detailed in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and can include:

- Synthetic N fertilizers; and
- Organic N fertilizers.

All other N input sources (e.g., crop residue N, atmospheric N deposition (other than as an indirect N2O emissions pathway) and soil N mineralization associated with soil management practices do not qualify for consideration.

All eligible N inputs on a mass basis are considered equal irrespective of their source.

4.5 The following conditions with respect to fertilizer nitrogen management must be met:

- Fertilizer N additions to the soil during a whole crop cycle are eligible for determination of the yearly fertilizer N rate irrespective of when N is applied during the calendar year or whether N application is split between calendar years for a single crop.

- During the project crediting period, adherence to 'Best Management Practices' (BMPs) as they relate to the application of synthetic and organic N fertilizer at the project site is required. These BMPs are related to N fertilizer formulation (or N content of organic additions) and dates and methods of application. Details of fertilizer BMPs are readily available for each US.state via state departments of agriculture and from federal agencies such as the Natural Resources Conservation Service (NRCS) and the USDA Farm Service Agency. More generally these BMPs are described in the Global 4R Nutrient (Fertilizer) Stewardship Framework (Right Source–Rate–Time–Place), published by the International Plant Nutrition Institute (IPNI).

- The project proponent must demonstrate that during each cropping season included in the project crediting period the total N rate to be applied to the project area is sufficient to generate expected annual yield similar to the average annual yield of the same crop(s) grown during the baseline period. Documentation required to demonstrate that this applicability condition has been met is described in Section 9.2.

4.6 Both direct and indirect pathways of N_2O emissions as outlined by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories are eligible under this methodology. Indirect N_2O emissions can occur in the following scenarios

- Following the volatilization of the gases NH_3 and NOx produced as a result of the N input to the project site and the subsequent re–deposition of these gases and their products NH4+ and NO3- to soils and waters beyond the project site;

- After leaching and runoff of N (mainly as NO_3-) applied to the project site enters receiving waters or soils beyond the project site (only applicable to regions where leaching and runoff is considered to occur – see Appendix A).

4.7 Projects must be implemented in the US only.

4.8 The following conditions with respect to cropping systems must be met:

- Projects located in the US including all fertilized agricultural crops where the product is harvested for food, livestock fodder or for another economic purpose must use Method 1 (described in section 8) to calculate direct N_2O emissions.

- Projects located in the NCR of the US that involve corn in row–crop systems such as continuous corn and rotations of corn–soybean or corn-soybean-wheat must use Method 2 (described in section 8) to calculate direct N_2O emissions.

- Projects located in the NCR that involve crops other than corn including crops in rotation with corn must use Method 1 to calculate direct N_2O emissions.

Projects must also state and justify ex-ante in the Project Document whether they will apply Method 1 or Method 2 as determined by their geographic location and cropping system. The same method must be applied to the calculation of direct N_2O emissions in the baseline and project case and used for the demonstration of additionality

4.9 The project crop area must be the same as or less than the baseline crop area in order to ensure that the same land area is used in emission reduction calculations.

4.10 Projects must not be on sites with 'organic' soils or Histosols, as defined by the US Soil Taxonomy. The unique properties of Histosols are a very high content of organic matter (OM) in the upper 80 cm (32 in) of the soils and no permafrost. The amount of organic matter is at least 20 to 30 percent by mass (200-300 g OM kg dry soil-1) in more than half of this thickness, or the horizon that is rich in organic matter rests on rock or rock rubble. Most Histosols are peats or mucks, which consist of more or less decomposed plant remains that accumulated in water, but some formed from forest litter or moss, or both, and are freely drained. USDA NRCS soils maps for individual fields can be used to determine whether a field is underlain by a soil series in the Histosol Order.

5 PROJECT BOUNDARY

Spatial boundary

The spatial boundary of the project encompasses both direct and indirect emissions of N_2O, and includes the project site where fertilizer N is directly applied as well as any additional soils and waters where byproducts of the fertilizer N input (such as the gases NH_3 and NOx, and their products NH_4^+ and NO_3^-) are re-deposited.

The project proponent must define the project site where fertilizer N is directly applied in the Project Document, but is not required to define the specific areas where byproducts may be re-deposited beyond the project site.

Temporal boundary

The project crediting period must follow the requirements for ALM projects focusing exclusively on emissions reductions of N_2O as set out in the most recent version of the VCS Standard.

Greenhouse gases

Table 1 summarizes the greenhouse gases accounted for in the calculations of baseline emissions and project emissions.

Table 1. Greenhouse gases and their sources

Source		Gas	Included?	Justification/Explanation
Baseline	Direct emissions synthetic fertilizer	CO_2	No	Not significant - de minimis
		CH_4	No	Not significant - de minimis
		N_2O	Yes	N_2O is the major emissions source from N fertilizer
	Indirect emissions	CO_2	No	Not significant - de minimis

Source		Gas	Included?	Justification/Explanation
	synthetic fertilizer	CH_4	No	Not significant - de minimis
		N_2O	Yes	N_2O is the major emissions source from N fertilizer
	Direct emissions organic fertilizer	CO_2	No	Not significant - de minimis
		CH_4	No	Not significant - de minimis
		N_2O	Yes	N_2O is the major emissions source from fertilizer N addition
	Indirect emissions organic fertilizer	CO_2	No	Not significant - de minimis
		CH_4	No	Not significant - de minimis
		N_2O	Yes	N_2O is the major emissions source from N fertilizer
Project	Direct emissions synthetic fertilizer	CO_2	No	Not significant - de minimis
		CH_4	No	Not significant - de minimis
		N_2O	Yes	N_2O is the major emissions source from N fertilizer
	Indirect emissions synthetic fertilizer	CO_2	No	Not significant - de minimis
		CH_4	No	Not significant - de minimis
		N_2O	Yes	N_2O is the major emissions source from N fertilizer
	Direct emissions organic fertilizer	CO_2	No	Not significant - de minimis
		CH_4	No	Not significant - de minimis
		N_2O	Yes	N_2O is the major emissions source from N fertilizer
	Indirect emissions organic fertilizer	CO_2	No	Not significant - de minimis
		CH_4	No	Not significant - de minimis
		N_2O	Yes	N_2O is the major emissions source from N fertilizer

Carbon pools

Table 2 summarizes the carbon pools included in projects using this methodology.

Soil carbon is the primary pool of concern for ALM methodologies. In accordance with VCS AFOLU requirements v3.0, methodologies targeting N_2O emission reductions need to account for any significant reductions in soil C stocks.

In this methodology reductions in N fertilizer rate resulting from project implementation will not result in significant (> 5% of the total CO_2e benefits from reduction in N_2O emissions) decreases in soil C stock. Evidence presented in Appendix B in the form of peer reviewed literature details how the soil C pool is deemed de minimis. Appendix B can be used for projects using this methodology as a criterion to exclude the soil C pool.

Table 2. Carbon pools considered in the methodology

Carbon Pool	Included?	Justification/Explanation
Above ground woody biomass	No	Not relevant or subject to significant change – de minimis

Carbon Pool	Included?	Justification/Explanation
Above ground non woody biomass	No	Not relevant or subject to significant change – de minimis
Below ground biomass	No	Not relevant or subject to significant change – de minimis
Litter	No	Not relevant or subject to significant change – de minimis
Dead wood	No	Not relevant or subject to significant change – de minimis
Soil	Yes	Change is nil or positive or (reduction is de minimis)
Wood products	No	Not relevant or subject to significant change – de minimis

6 PROCEDURE FOR DETERMINING THE BASELINE SCENARIO

The baseline scenario is the continuation of the historical cropping practices where, in the absence of the project activity, N fertilizer rate is applied in a business as usual (BAU) manner, resulting in higher emissions of N_2O from the soil when compared to a situation where the project is implemented and the application of lower N fertilizer rate results in lower emissions of N_2O.

The baseline emissions are the amount of N_2O that would have been emitted to the atmosphere during the project crediting period under the N rate practice that would have been in place had the project not been implemented.

The determination of baseline N_2O emissions is carried out using one of two Approaches. Both Approaches use a yield-goal calculation method to generate a baseline fertilizer N application rate, from which emissions of N_2O are calculated. Approach 1 derives the baseline N rate from producer-specific N fertilizer management records, and Approach 2 derives the baseline N rate from county-level records aggregated by the USDA National Agricultural Statistics Service: USDA crop yield data in conjunction with standard state-specific University-recommended yield-goal based equations for calculating N rates from these yields for the period in question.

Due to its finer spatial resolution (site specificity), project proponents must use Approach 1 if data is available. Approach 2 (county scale data) can be used if relevant site-specific records are not available or verifiable for Approach 1. The same Approach must be applied to synthetic N fertilizer and organic N fertilizer if both kinds of fertilizers have been applied during the baseline period.

Approach 1

The baseline N fertilizer rate is determined from the project proponents' management records for at least the previous five years (monoculture) or six years (e.g., three cycles of a two crop rotation, or two cycles of a three crop rotation) prior to the proposed project implementation year.

Management records from which baseline fertilizer N rate can be directly determined is required under this Approach. Examples of these include synthetic fertilizer purchase and application rate records, as well as manure application rate and manure N content data.

Determination of the baseline N_2O emissions must be based on an average of the previous N rate applications for the specific crop(s). A worked example of a baseline N rate calculation using Approach 1 is given in Appendix C.

Approach 2

If the baseline fertilizer N rate for the specific crop(s) cannot be established from project proponent records (Approach 1), then Approach 2 can be used. With Approach 2, the baseline fertilizer N rate is calculated from crop yield data at the county level (available from the United States Department of Agriculture – National Agricultural Statistics Service (USDA – NASS)) and equations for determining fertilizer N rate recommendations based on yield goal estimates (found in e.g., state department of agriculture and university agricultural extension documents).

7 PROCEDURE FOR DEMONSTRATING ADDITIONALITY

Additionality is assessed through the performance method. The performance method requires projects to meet with requirements on regulatory surplus and exceed the performance benchmark specified below.

Regulatory Surplus

Project proponents meet the requirements for regulatory surplus if:

There is no mandatory law, statute or other regulatory framework in place at the local, state, or federal level, requiring producers to reduce fertilizer N input rate below that of a BAU scenario.

Appendix D provides more information and presents a list of regulations at Federal and State level that deal with practices relating to synthetic and organic N fertilizer management in the agricultural sector. Project developers must consider and evaluate the applicability of all such regulations in the context of the proposed project in order to satisfy the regulatory surplus requirements.

Performance Benchmark

Projects proponents must exceed a performance benchmark threshold that represents BAU. The BAU value is identical to the baseline value for N fertilizer application rate. The baseline value for N fertilizer rate is equivalent to the widespread and general practice of producers to apply N fertilizer rates based upon recommendations derived from yield goal calculations known to overestimate crop needs.

Reductions in N fertilizer rate and therefore N_2O emissions below the BAU site specific value (Approach 1) or below the BAU value in the county where the project is to be conducted (Approach 2) will result in a project exceeding the performance benchmark. The benchmark is defined in terms of N_2O emissions (Mg $CO_2e\ ha^{-1}$). Detailed examples using Approach 1 and Approach 2 to determine the benchmark are shown in Appendix C. Evidence for the wide-scale, historic, and continued adoption of the yield-goal approach, and therefore its legitimacy as a performance benchmark for demonstrating additionality in US crop-based agriculture is given in Appendix E.

Further discussion on why Approach 2 is conservative and the trade-offs between false positives (the crediting of activities that are not additional) and false negatives (the exclusion of activities that are additional) is also presented in Appendix E.

The procedures described below are the requirements for determining the benchmark for a crop grown in a single project site using Approach 2.

- Identify project site
- Identify project crop
- Identify years in which crop has been harvested in project site.
- Gather data on crop yield from these years in relevant U.S. county from USDA-NASS
- Use equation C2 (Appendix C) or other relevant equation to calculate predicted crop yield (YG_t)
- Incorporate YG_t into relevant 'yield goal' equation for calculating N rate (e.g., equation C1 in Appendix C)
- Calculate annual N rates based upon field rotation and management (e.g., incorporating N credits)
- Calculate average annual N rate (i.e., baseline N rate) from all annual N rates
- Reduce N rate below the baseline N rate during project crediting period
- Record and maintain project N rate records

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

All emissions of N_2O (baseline and project, direct and indirect) are reported in units of Megagram of carbon dioxide equivalents (Mg CO_2e). One (1) Mg is equivalent to 1×10^6g or one (1) metric Ton or one (1) tonne.

Emissions for baseline and project period are calculated on a per hectare (ha) of land basis.

In the calculations below, year t is the 12-month period following the first input of N fertilizer dedicated to a particular crop, or the period of time following this input prior to an N input dedicated to a separate and subsequent crop at the same project site,

The subscripts B (e.g., $F_{B\ SN,\ t}$) and P (e.g., $F_{P\ SN,\ t}$) are added to distinguish the terms for baseline and project emission factors, respectively. All other factors without these subscripts will be applicable for use in both project and baseline emission calculations.

In calculating direct and indirect emissions of N_2O, the methodology utilizes terminology and scientific rationale presented in the most recent 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

8.1 Baseline Emissions

Baseline emissions can be calculated by the following equation:

$$N_2O_{B\ total,\ t} = N_2O_{B\ direct,\ t} + N_2O_{B\ indirect,\ t} \quad (1)$$

Where:

$N_2O_{B\ total,\ t}$ Total baseline N_2O emissions, Mg CO_2e ha^{-1} in year t;

$N_2O_{B\ direct,\ t}$	Direct baseline N_2O emissions from the project site, Mg CO_2e ha^{-1} in year t;
$N_2O_{B\ indirect,\ t}$	Indirect baseline N_2O emissions beyond the project site, Mg CO_2e ha^{-1} in year t.

Direct emissions

Method 1

The direct baseline nitrous oxide emissions from nitrogen fertilization for Method 1 can be calculated using the following equations:

$$N_2O_{B\ direct,\ t} = (F_{B\ SN,\ t} + F_{B\ ON,\ t}) * EF_{BDM1} * N_2O_{MW} * N_2O_{GWP} \quad (2)$$

$$F_{B\ SN,\ t} = M_{B\ SF,\ t} * NC_{B\ SF} \quad (3)$$

$$F_{B\ ON,\ t} = M_{B\ OF,\ t} * NC_{B\ OF} \quad (4)$$

Where:

$F_{B\ SN,\ t}$	Baseline synthetic N fertilizer applied, Mg N ha^{-1} in year t;
$F_{B\ ON,\ t}$	Baseline organic N fertilizer applied, Mg N ha^{-1} in year t;
$M_{B\ SF,\ t}$	Mass of baseline N containing synthetic fertilizer applied, Mg ha^{-1} in year t;
$M_{B\ OF,\ t}$	Mass of baseline N containing organic fertilizer applied, Mg ha^{-1} in year t;
$NC_{B\ SF}$	N content of baseline synthetic fertilizer applied, g N (100g fertilizer)$^{-1}$;
$NC_{B\ OF}$	N content of baseline organic fertilizer applied g N (100g fertilizer)$^{-1}$;
EF_{BDM1}	Emission factor for baseline direct N_2O emissions from N inputs Mg N_2O–N (Mg N input)$^{-1}$ (IPCC default Tier 1 = 0.01. See Appendix F);
N_2O_{MW}	Ratio of molecular weights of N_2O to N (44/28), Mg N_2O (Mg N)$^{-1}$;
N_2O_{GWP}	Global Warming Potential for N_2O, Mg CO_2e (Mg N_2O)$^{-1}$ (IPCC default = 310. See Appendix F).

Method 2

Direct emissions of N_2O will be calculated using a NCR derived (IPCC Tier 2) equation for baseline and project emissions. See Appendix G. The direct baseline nitrous oxide emissions from nitrogen fertilization for Method 2 can be calculated using the following equations:

$$N_2O_{B\ direct,\ t} = (F_{B\ SN,\ t} + F_{B\ ON,\ t}) * EF_{BDM2} * N_2O_{MW} * N_2O_{GWP} \quad (5)$$

$$F_{B\ SN,\ t} = M_{B\ SF,\ t} * NC_{B\ SF} \quad (3)$$

$$F_{B\ ON,\ t} = M_{B\ OF,\ t} * NC_{B\ OF} \quad (4)$$

$$EF_{BDM2} = 6.7 * 10^{-4} * \exp\ ([6.7 * F_{B\ SN,\ t} + F_{B\ ON,\ t}] - 1) / (F_{B\ SN,\ t} + F_{B\ ON,\ t}) \quad (6)$$

Where:

EF_{BDM2} Emission factor for baseline direct N_2O emissions from N inputs Mg N_2O–N (Mg N input)$^{-1}$. See Appendix G for details of emission factor calculation.

All other terms are as for Method 1.

For method 1 and method 2, the amounts of applied mineral nitrogen fertilizers ($F_{B\ SN,\ t}$) and of applied organic nitrogen fertilizers ($F_{B\ ON,\ t}$) are not adjusted for the amounts of NH_3 and NO_x volatilization after application to soil. Reasons for the removal are given in 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Volume 4, Chapter 11, Note 11).

The baseline fertilizer N rate value calculated using Approach 2 represents the product of the mass and the N content of the synthetic N containing fertilizer, i.e., $M_{B\ SF,\ t}$ * $NC_{B\ SF}$, and as such can be used directly as the value of $F_{B\ SN,\ t}$. Approach 2 is not applicable for the calculation of the baseline organic fertilizer N rate, therefore the value of $F_{B\ ON,\ t} = 0$.

Indirect emissions

The indirect baseline nitrous oxide emissions from nitrogen fertilization can be calculated using the following equations:

$$N_2O_{B\ indirect,\ t} = N_2O_{B\ volat,\ t} + N_2O_{B\ leach,\ t} \quad (7)$$

$$N_2O_{B\ volat,\ t} = [(F_{B\ SN,\ t} * Frac_{GASF}) + (F_{B\ ON,\ t} * Frac_{GASM})] * EF_{BIV} * N_2O_{MW} * N_2O_{GWP} \quad (8)$$

$$N_2O_{B\ leach,\ t} = (F_{B\ SN,\ t} + F_{B\ ON,\ t}) * Frac_{LEACH} * EF_{BIL} * N_2O_{MW} * N_2O_{GWP} \quad (9)$$

Where:

$N_2O_{B\ indirect,\ t}$ Indirect baseline N_2O emissions beyond the project site, Mg CO_2e ha^{-1} in year t;

$N_2O_{B\ volat,\ t}$ Indirect baseline N_2O emissions produced from atmospheric deposition of N volatilized as a result of N application at the project site, Mg CO_2e ha^{-1} in year t;

$N_2O_{B\ leach,\ t}$ Indirect baseline N_2O emissions produced from leaching and runoff of N in regions where leaching and runoff occurs, as a result of N application at the project site, Mg CO_2e ha^{-1} in year t;

$F_{B\ SN,\ t}$ Baseline synthetic N fertilizer applied, Mg N ha^{-1} in year t;

$F_{B\ ON,\ t}$ Baseline organic N fertilizer applied, Mg N ha^{-1} in year t;

$Frac_{GASF}$ Fraction of all synthetic N added to baseline soils that volatilizes as NH_3 and NO_x, dimensionless (IPCC default Tier 1 = 0.10. See Appendix F);

$Frac_{GASM}$ Fraction of all organic N added to baseline soils that volatilizes as NH_3 and NO_x, dimensionless (IPCC default Tier 1 = 0.20. See Appendix F);

$Frac_{LEACH}$ Fraction of N added (synthetic or organic) to baseline soils that is lost through leaching and runoff, in regions where leaching and runoff occurs, dimensionless (IPCC default Tier 1 = 0.30. See Appendix A and F);

EF_{BIV} Emission factor for baseline N_2O emissions from atmospheric deposition of N on soils and water surfaces, [Mg N_2O–N (Mg NH_3–N + NO_x–N volatilized)$^{-1}$] (IPCC default Tier 1 = 0.01. See Appendix F);

EF_{BIL} Emission factor for baseline N_2O emissions from N leaching and runoff, Mg N_2O–N (Mg N leached and runoff)$^{-1}$ (IPCC default Tier 1 = 0.0075. See Appendix F);

N_2O_{MW} Ratio of molecular weights of N_2O to N (44/28), Mg N_2O (Mg N)$^{-1}$;

N_2O_{GWP} Global Warming Potential for N_2O, Mg CO_2e (Mg N_2O)$^{-1}$ (IPCC default = 310. See Appendix F).

At project sites where leaching and runoff do not occur (see Appendix A), indirect N_2O emissions are calculated by removing the factor $N_2O_{B\ leach,\ t}$ from equation 7.

8.2 Project Emissions

Project emissions can be calculated by the following equation:

$$N_2O_{P\ total,\ t} = N_2O_{P\ direct,\ t} + N_2O_{P\ indirect,\ t} \quad (10)$$

Where:

$N_2O_{P\ total,\ t}$ Total project N_2O emissions, Mg CO_2e ha^{-1} in year t;

$N_2O_{P\ direct,\ t}$ Direct project N_2O emissions from the project site, Mg CO_2e ha^{-1} in year t;

$N_2O_{P\ indirect,\ t}$ Indirect project N_2O emissions beyond the project site, Mg CO_2e ha^{-1} in year t.

Direct emissions

Method 1

The project direct nitrous oxide emissions from nitrogen fertilization can be calculated using equations as follows:

$$N_2O_{P\ direct,\ t} = (F_{P\ SN,\ t} + F_{P\ ON,\ t}) * EF_{PDM1} * N_2O_{MW} * N_2O_{GWP} \quad (11)$$

$$F_{P\ SN,\ t} = M_{P\ SF,\ t} * NC_{P\ SF} \quad (12)$$

$$F_{P\ ON,\ t} = M_{P\ OF,\ t} * NC_{P\ OF} \quad (13)$$

Where:

$F_{P\ SN,\ t}$ Project synthetic N fertilizer applied, Mg N ha^{-1} in year t;

$F_{P\ ON,\ t}$ Project organic N fertilizer applied, Mg N ha^{-1} in year t;

$M_{P\ SF,\ t}$ Mass of project N containing synthetic fertilizer applied, Mg ha^{-1} in year t;

$M_{P\ OF,\ t}$ Mass of project N containing organic fertilizer applied, Mg ha^{-1} in year t;

$NC_{P\ SF}$ N content of project synthetic fertilizer applied g N (100g fertilizer)$^{-1}$;

$NC_{P\ OF}$ N content of project organic fertilizer applied g N (100g fertilizer)$^{-1}$;

EF_{PDM1} — Emission factor for project N_2O emissions from N inputs, Mg N_2O–N (Mg N input)$^{-1}$ (IPCC default = 0.01. See Appendix F);

N_2O_{MW} — Ratio of molecular weights of N_2O to N (44/28), Mg N_2O (Mg N)$^{-1}$;

N_2O_{GWP} — Global Warming Potential for N_2O, Mg CO_2e (Mg N_2O)$^{-1}$ (IPCC default = 310. See Appendix F).

Method 2

The direct project nitrous oxide emissions from nitrogen fertilization for Method 2 can be calculated using the following equations:

$$N_2O_{P\ direct,\ t} = (F_{P\ SN,\ t} + F_{P\ ON,\ t}) * EF_{PDM2} * N_2O_{MW} * N_2O_{GWP} \quad (14)$$

$$F_{P\ SN,\ t} = M_{P\ SF,\ t} * NC_{P\ SF} \quad (12)$$

$$F_{P\ ON,\ t} = M_{P\ OF,\ t} * NC_{P\ OF} \quad (13)$$

$$EF_{PDM2} = 6.7 * 10^{-4} * \exp([6.7 * F_{P\ SN,\ t} + F_{P\ ON,\ t}] – 1) / (F_{P\ SN,\ t} + F_{P\ ON,\ t}) \quad (15)$$

Where:

EF_{PDM2} — Emission factor for project direct N_2O emissions from N inputs Mg N_2O–N (Mg N input)$^{-1}$. See Appendix **G** for details of emission factor calculation.

All other terms are as for Method 1.

For method 1 and method 2, the amounts of applied mineral nitrogen fertilizers ($F_{B\ SN,\ t}$) and of applied organic nitrogen fertilizers ($F_{B\ ON,\ t}$) are not adjusted for the amounts of NH_3 and NO_x volatilization after application to soil. Reasons for the removal are given in 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Volume 4, Chapter 11, Note 11).

Indirect emissions

The indirect project nitrous oxide emissions from nitrogen fertilization can be calculated using the following equations:

$$N_2O_{P\ indirect,\ t} = N_2O_{P\ volat,\ t} + N_2O_{P\ leach,\ t} \quad (16)$$

$$N_2O_{P\ volat,\ t} = [(F_{P\ SN,\ t} * Frac_{GASF}) + (F_{P\ ON,\ t} * Frac_{GASM})] * EF_{PIV} * N_2O_{MW} * N_2O_{GWP} \quad (17)$$

$$N_2O_{P\ leach,\ t} = (F_{P\ SN,\ t} + F_{P\ ON,\ t}) * Frac_{LEACH} * EF_{PIL} * N_2O_{MW} * N_2O_{GWP} \quad (18)$$

Where:

$N_2O_{P\ indirect,\ t}$ — Indirect project N_2O emissions beyond the project site, Mg CO_2e ha^{-1} in year t;

$N_2O_{P\ volat,\ t}$ — Indirect project N_2O emissions produced from atmospheric deposition of N volatilized as a result of N application at the project site, Mg CO_2e ha^{-1} in year t;

$N_2O_{P\ leach,\ t}$	Indirect project N_2O emissions produced from leaching and runoff of N in regions where leaching and runoff occurs, as a result of N application at the project site, Mg CO_2e ha^{-1} in year t;
$F_{P\ SN,\ t}$	Project synthetic N fertilizer applied adjusted for volatilization as NH_3 and NO_x, and leaching and runoff where applicable, Mg N ha^{-1} in year t;
$F_{P\ ON,\ t}$	Project organic N fertilizer applied adjusted for volatilization as NH_3 and NO_x, and leaching and runoff where applicable, Mg N ha^{-1} in year t;
$Frac_{GASF}$	Fraction of all synthetic N added to project soils that volatilizes as NH_3 and NO_x, dimensionless (IPCC default Tier 1 = 0.10. See Appendix F);
$Frac_{GASM}$	Fraction of all organic N added to project soils that volatilizes as NH_3 and NO_x, dimensionless (IPCC default Tier 1 = 0.20. See Appendix F);
$Frac_{LEACH}$	Fraction of N added (synthetic or organic) to project soils that is lost through leaching and runoff, in regions where leaching and runoff occurs, dimensionless (IPCC default Tier 1 = 0.30. See Appendix A and F);
EF_{PIV}	Emission factor for project N_2O emissions from atmospheric deposition of N on soils and water surfaces, [Mg N_2O–N (Mg NH_3–N + NO_x–N volatilized)$^{-1}$] (IPCC default Tier 1 = 0.01. See Appendix F);
EF_{PIL}	Emission factor for project N_2O emissions from N leaching and runoff, Mg N_2O–N (Mg N leached and runoff)$^{-1}$ (IPCC default Tier 1 = 0.0075. See Appendix F);
N_2O_{MW}	Ratio of molecular weights of N_2O to N (44/28), Mg N_2O (Mg N)$^{-1}$;
N_2O_{GWP}	Global Warming Potential for N_2O, Mg CO_2e (Mg N_2O)$^{-1}$ (IPCC default = 310. See Appendix F).

At project sites where leaching and runoff do not occur (see Appendix A), project indirect N_2O emissions are calculated by removing the factor $N_2O_{P\ leach,\ t}$ from equation 16.

8.3 Leakage

Leakage risks from increased N_2O emissions and other greenhouse gas emissions, and decreased C pools outside the ALM project boundary are not relevant and are not included in emissions calculations due to the reasons described below:

Leakage risks are negligible for ALM projects involving cropland management activities because the land in the project scenario remains maintained for commodity production. Therefore, no production activities outside the project boundary are required to compensate for a productivity decline.

Crop producers are highly risk averse and will not intentionally suffer reduced crop yields. Reducing N rates and the adoption of N rates based on economic optimization will not result in a reduction in crop yield. Extensive historical and current data from Midwestern states at typical crop-to-fertilizer price ratios indicate that there will be no significant change in crop yield as a result of lowering N fertilizer rate from current rates to the economic optimum (ISU 2004, Sawyer et al. 2006, Hoben et al. 2011). Consequently, with no reduction in productivity at the project site there will be no associated incentive for a shift of activity or increased production outside of the project site, which might in turn result in increased N fertilizer use and N_2O emissions. With no yield reduction there will also be no decrease in soil C input and therefore no change in soil C sequestration due to project activities (see section 5 and Appendix B). The leakage potential is therefore negligible.

Moreover, although accounting for 'positive leakage' is not eligible, less available N in the soil will result in a reduction in other gaseous and hydrologic N pollutants (e.g., NH_3, NO_x, and NO_3^-).

8.4 Summary of GHG Emission Reduction and/or Removals

The uncertainty associated with a reduction in N_2O emissions brought about by a reduction in N rate between the baseline period and the project period is calculated as:

$$N_2O\ Emissions_{(RED\ UNC)} \quad [1 - \{0.63 * \exp(-40 * [N_{Proj}]^2)\}] * 100 \qquad (19)$$

Where:

N_2O Emissions $_{(RED\ UNC)}$ Uncertainty in N_2O emissions reductions associated with a reduction in N rate, %;

N_{Proj} = $F_{P\ SN,\ t} + F_{P\ ON,\ t}$ project N input, Mg N ha^{-1} yr^{-1}.

Equation (19) is applicable to projects that determine their baseline N rate (and therefore baseline N_2O emissions) using either Approach 1 or Approach 2 (section 6). Further details of how emissions uncertainty is derived are given in Appendix G.

Project proponents will use equation (19) to calculate emissions reductions uncertainties (%) for a project. Confidence deductions as a result of uncertainty will be applied using the conservative factors specified in the CDM Meth Panel guidance on addressing uncertainty in its Thirty Second Meeting Report, Appendix 14 (Table 3 below).

Table 3: Conservativeness factors for emissions reductions based upon uncertainty at 95% confidence level.

Uncertainty range at 95% confidence level of project emissions reductions§	Conservativeness factor	Uncertainty deduction*
< ± 15%	1.000	0.000
> ± 15% ≤ ± 30%	0.943	0.057
> ± 30% ≤ ± 50%	0.893	0.107
> ± 50% ≤ ± 100%	0.836	0.164

§ Uncertainty in emissions reductions does not exceed 100% (see Appendix G).
* Where uncertainty in emissions reductions is < ± 15%, no deductions will be applied.
Uncertainty deduction (UNC) = (1 – Conservativeness factor). See equation (20).

Emissions reductions and calculations of VCUs

Equation (20) calculates the N_2O emission reductions brought about by project implementation:

$$N_2O_{PR,\ t} = [(N_2O_{B\ total,\ t} - N_2O_{P\ total,\ t}) * A_P] * (1 - LK) * (1 - UNC) \qquad (20)$$

Where:

$N_2O_{PR,\,t}$	Reduction in total N_2O emissions brought about by project implementation, Mg CO_2e in year t;
$N_2O_{B\ total,\,t}$	Total baseline N_2O emissions within the project spatial boundary as a result of N application at the project site, Mg CO_2e ha^{-1} in year t;
$N_2O_{P\ total,\,t}$	Total project N_2O emissions within the project spatial boundary as a result of N application at the project site, Mg CO_2e ha^{-1} in year t;
A_P	Project area, ha;
LK	Leakage deduction (set as 0 in this methodology, as described in section 8.3);
UNC	Uncertainty deduction (set as in Table 3 [this section] in this methodology).

Equation (21) calculates the amount of VCUs issued:

$$VCU_t = N_2O_{PR,\,t} * (1 - BUF) \quad (21)$$

Where:

VCU_t	Verified Carbon Units (VCUs) at time t, Mg CO_2e;
BUF	Buffer deduction (set as 0 in this methodology).

9 MONITORING

9.1 Data and Parameters Available at Validation

Data Unit / Parameter:	$M_{B\ SF,\,t}$
Data unit:	Mg ha^{-1} yr^{-1}
Description:	Baseline synthetic N containing fertilizer applied
Source of data:	Project proponent records (Approach 1)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	Approach 2 calculates baseline fertilizer N rate = ($M_{B\ SF,\,t}$ * $NC_{B\ SF}$), and is substituted into equation 3 to calculate $F_{B\ SN,\,t}$.

Data Unit / Parameter:	$M_{B\ OF,\,t}$
Data unit:	Mg ha^{-1} yr^{-1}

Description:	Baseline organic N containing fertilizer applied
Source of data:	Project proponent records (Approach 1)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	Approach 2 is not applicable for the calculation of $M_{B\ OF,\ t}$.

Data Unit / Parameter:	$NC_{B\ SF}$
Data unit:	g N (100g fertilizer)$^{-1}$
Description:	Nitrogen content of baseline synthetic fertilizer applied
Source of data:	Project proponent records (Approach 1)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	Approach 2 calculates baseline fertilizer N rate = ($M_{B\ SF,\ t}$ * $NC_{B\ SF}$), and is substituted into equation 3 to calculate $F_{B\ SN,\ t}$.

Data Unit / Parameter:	$NC_{B\ OF}$
Data unit:	g N (100g fertilizer)$^{-1}$
Description:	Nitrogen content of baseline organic fertilizer applied
Source of data:	Project proponent records (Approach 1)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	Approach 2 is not applicable for the calculation of $NC_{B\ OF}$.

Data Unit / Parameter:	Baseline Crop yield
Data unit:	Mg ha^{-1} yr^{-1}

Description:	Crop yield (standard reporting method for particular crop, e.g., dry grain yield)
Source of data:	Project proponent records (Approach 1) or county level data (Approach 2)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	Baseline Crop area
Data unit:	Hectare (ha)
Description:	Area of crop(s) planted, from which baseline fertilizer N rate determined
Source of data:	Project proponent records (Approach 1 and 2)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	The baseline crop area must encompass the project crop area in order to ensure that the same land area is used in emission reduction calculations.

Data Unit / Parameter:	$Frac_{GASF}$
Data unit:	Dimensionless
Description:	Fraction of all synthetic N added to project soils that volatilizes as NH_3 and NO_x
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.10)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	$Frac_{GASM}$
Data unit:	Dimensionless

Description:	Fraction of all organic N added to project soils that volatilizes as NH_3 and NO_x,
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.20)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	$Frac_{LEACH}$
Data unit:	Dimensionless
Description:	Fraction of N added (synthetic or organic) to project soils that is lost through leaching and runoff, in regions where leaching and runoff occurs
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.30)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	EF_{BDM1}
Data unit:	Mg N_2O–N (Mg N input)$^{-1}$
Description:	Emission factor for baseline direct N_2O emissions from N inputs (Method 1)
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.01)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	EF_{BDM2}
Data unit:	Mg N_2O–N (Mg N input)$^{-1}$

Description:	Emission factor for baseline direct N_2O emissions from N inputs (Method 2)
Source of data:	Empirical research on producer fields throughout Michigan
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	Parameter only valid in North Central Region of the US (Appendix G; Hoben et al. 2011).

Data Unit / Parameter:	EF_{BIV}
Data unit:	Mg N_2O–N (Mg NH_3–N + NO_x–N volatilized)$^{-1}$
Description:	Emission factor for baseline N_2O emissions from atmospheric deposition of N on soils and water surfaces
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.01)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	EF_{BIL}
Data unit:	Mg N_2O–N (Mg N leached and runoff)$^{-1}$
Description:	Emission factor for baseline N_2O emissions from N leaching and runoff,
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.0075)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	EF_{PDM1}
Data unit:	Mg N_2O–N (Mg N input)$^{-1}$

Description:	Emission factor for project direct N_2O emissions from N inputs (Method 1)
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.01)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	EF_{PDM2}
Data unit:	Mg N_2O–N (Mg N input)$^{-1}$
Description:	Emission factor for project direct N_2O emissions from N inputs (Method 2)
Source of data:	Empirical research on producer fields throughout Michigan
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	EF_{PIV}
Data unit:	Mg N_2O–N (Mg NH_3–N + NO_x–N volatilized)$^{-1}$
Description:	Emission factor for project N_2O emissions from atmospheric deposition of N on soils and water surfaces
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.01)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

Data Unit / Parameter:	EF_{PIL}
Data unit:	Mg N_2O–N (Mg N leached and runoff)$^{-1}$
Description:	Emission factor for project N_2O emissions from N

	leaching and runoff,
Source of data:	2006 IPCC Guidelines for National Greenhouse Gas Inventories (default Tier 1 = 0.0075)
Justification of choice of data or description of measurement methods and procedures applied:	
Any comment:	

9.2 Data and Parameters Monitored

Data Unit / Parameter:	$M_{P\ SF,\ t}$
Data unit:	Mg N yr^{-1}
Description:	Mass of project synthetic N containing fertilizer applied
Source of data:	Project proponent records
Description of measurement methods and procedures to be applied:	Generally accepted field application methods using calibrated applicators of known capacity for fertilizer mass or volume determination
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	Verify calibration and capacity of applicators
Any comment:	

Data Unit / Parameter:	$M_{P\ OF,\ t}$
Data unit:	Mg N yr^{-1}
Description:	Mass of project organic N containing fertilizer applied
Source of data:	Project proponent records
Description of measurement methods and procedures to be applied:	Generally accepted methods using calibrated applicators of known weight/volume for liquid and solid organic material application
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	Verify calibration and capacity of applicators and number of loads applied
Any comment:	

Data Unit / Parameter:	$NC_{P\ SF}$
Data unit:	g N (100g fertilizer)$^{-1}$
Description:	Nitrogen content of project synthetic fertilizer applied
Source of data:	Project proponent records
Description of measurement methods and procedures to be applied:	Generally accepted procedures for sampling, handling and analysis of bulk fertilizer
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	Verify fertilizer is from accredited source*
Any comment:	

Data Unit / Parameter:	$NC_{P\ OF}$
Data unit:	g N (100g fertilizer)$^{-1}$
Description:	Nitrogen content of project organic fertilizer applied
Source of data:	Project proponent records
Description of measurement methods and procedures to be applied:	Generally accepted sampling and handling procedures for organic materials. Laboratory analysis for total N using total Kjeldahl Nitrogen [TKN] or total N by combustion)
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	Verify N content from laboratory analysis documentation
Any comment:	

Data Unit / Parameter:	Project Crop area
Data unit:	Hectare (ha)
Description:	Area of crop(s) planted, from which project fertilizer N rate determined
Source of data:	Project proponent records
Description of measurement methods and	As per requirements of VCS version 3 “Project location for AFOLU projects must be specified

procedures to be applied:	using geodetic polygons to delineate the geographic area of each AFOLU project activity and provided in a KML file.
Frequency of monitoring/recording:	Each project crediting period
QA/QC procedures to be applied:	Verify file(s) coincide with project field(s) geographic boundary
Any comment:	

*The formulation of the synthetic N containing fertilizer must also be verified. From this the N content (% of mass) can be determined. Farmers' records must be cross-checked with records from synthetic and organic N fertilizer suppliers. In case of discrepancies between the records of the farmers and those from suppliers of synthetic and organic N containing fertilizers, the most conservative value(s) must be taken.

To demonstrate the total amount of N to be applied to the project area during a cropping season is sufficient to generate expected annual yield similar to the average annual yield of the same crop(s) during the baseline period as required in Section 4 (Fertilizer Nitrogen Management), the project proponent is required to provide one of the following two forms of evidence (1 or 2 below).

1. Demonstrate consistency with the most recent state or regional N rate recommendations provided by the University Agriculture Extension Service, state department of agriculture, or a federal agency such as the USDA Natural Resources Conservation Service (NRCS) or Farm Service Agency (FSA). In this context, "consistency" means that the total amount of N to be applied to the project area during a cropping season must be equal to or greater than 80% of the lowest estimate of N rate range recommended for the relevant crop(s) in the region in which they are grown. This can be demonstrated using one of the two approaches below (a or b below):

    a. Consistent with the total N rate recommended in official publications from these organizations, such as extension bulletins or soil test lab reports.

    b. Consistent with data output from approved N rate calculators. Examples of approved N rate calculators include the Iowa State University corn nitrogen rate calculator (http://extension.agron.iastate.edu/soilfertility/nrate.aspx) for multiple Midwest states, and the University of Wisconsin corn N rate calculator (http://ipcm.wisc.edu/iPhone/tabid/120/Default.aspx) for Wisconsin, both of which calculate the profitable N rate range for corn around the maximum return to nitrogen (MRTN) rate. Other N rate calculators can be used provided they have been made available to the public by a University Agriculture Extension Service, state department of agriculture, or a federal agency, such as the USDA NRCS or FSA. A worked example demonstrating the use of the Iowa State University corn nitrogen calculator is shown in Appendix H.

2. Written certification provided by a professional crop advisor (see below) stating that total amount of N to be applied to the project area during a cropping season is sufficient to generate expected annual yield similar to the average annual yield of the same crop(s) grown during the baseline period.

The professional crop advisor must be: (a) a Certified Crop Advisor (CCA) certified by the American Society of Agronomy (ASA); (b) a Certified Professional Crop Consultant (CPCC) certified by the Soil and Water Conservation Society (SWCS); (c) a professional staff member of a University Agricultural Extension Service; (c) a professional staff member of the USDA NRCS or FSA; (d) a professional staff member of a state agriculture agency in the state in which the project is located; or (e) an equivalent professional crop advisor as demonstrated by similar professional qualifications.

9.3 Description of the Monitoring Plan

The data and parameters required for baseline validation and during the project period are detailed in sections 9.1 and 9.2, respectively.

Information on accepted methods for sampling and handling, and measuring mass and N content of fertilizer can be found in state university agricultural extension documents.

Data for monitored parameters are derived from farmer records that are used for compliance with a myriad of farm-related programs, including state and federal BMPs. These farmer records also are consistent with project documents required for verification during the project period.

10 APPENDICES

APPENDIX A - Equations for determining if leaching and runoff occur at project site

The approach presented here uses default (Tier 1) values for leaching and run-off from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, and the ratio of growing season values of precipitation to potential evapotranspiration.

A project site is considered to have a $Frac_{LEACH}$ default value of 0.30 kg N (kg N additions)$^{-1}$) when:

$$Precip_{GS} / PET_{GS} \geq 1.00 \quad (A1)$$

A project site is considered to have a $Frac_{LEACH}$ default value of 0.00 kg N (kg N additions)$^{-1}$) when:

$$Precip_{GS} / PET_{GS} < 1.00 \quad (A2)$$

Where:

$Precip_{GS}$	=	Precipitation during the growing season, mm;
PET_{GS}	=	Potential evapotranspiration during the growing season, mm.

The growing season is considered to occur from May – September inclusive, unless otherwise verifiable. Planting and harvesting or frost records can be used to verify that the growing season is other than May – September. While this period is appropriate for corn over most of the NCR, in southern parts of the US corn can be planted a number of weeks prior to the beginning of May. Also, for example, if winter annual crops such as winter wheat and fall canola are grown, the appropriate growing season may be October – July.

Where crop irrigation is employed, irrigation water is considered equivalent to rainfall, and as such, project proponents will add irrigation water input to precipitation data to calculate total precipitation during the growing season or annually as required. Water from drip irrigation is excluded.

Average values for precipitation and irrigation water and potential evapotranspiration for baseline determination are calculated from the same time period used to determine baseline fertilizer N rate, i.e., consistent with project proponents' records (Approach 1) or county level data (Approach 2).

Information sources for determining if leaching and runoff occur at project site

If site specific data for precipitation and potential evapotranspiration are not readily available, data from local meteorological stations can be used. A centralized information source to identify these stations in the US can be found at the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) station information webpage: http://www.weather.gov/tg/siteloc.shtml. Archived data for all US meteorological sites can be found at the National Climatic Data Center (NCDC): http://lwf.ncdc.noaa.gov/oa/climate/stationlocator.html.

Individual US states may also have meteorological data available through academic or other institutions. In Michigan for example, annual precipitation and potential evapotranspiration data can be obtained from the Michigan Automated Weather Network (MAWN): http://www.agweather.geo.msu.edu/mawn.

Potential Evapotranspiration (PET) at project sites may also be calculated using the FAO Penman–Monteith equation. More information can be found in Allen et al. (1998).

APPENDIX B - Evidence relating to exclusion of soil C in methodology accounting

Appendix B can be used for projects using this methodology as a criterion to exclude the soil C pool.

Soil carbon is the primary pool of concern for ALM methodologies. In accordance with VCS AFOLU requirements v3.0, methodologies targeting N_2O emission reductions need to account for any significant reductions in soil C stocks.

In this methodology reductions in N fertilizer rate resulting from project implementation will not result in significant (> 5% of the total CO_2e benefits from reduction in N_2O emissions) decreases in soil C stock. Peer reviewed literature details how the soil C pool is deemed de minimis.

N fertilizer can increase soil C stocks by increasing crop growth and associated rates of crop residue production. Because this methodology will not result in significant crop growth (yield) declines and therefore no declines in residue inputs, there can be no associated decline in soil C stocks. In fact available evidence suggests that excess N can speed decomposition (Parton et al. 2007) and thereby lower (Khan et al. 2007) or maintain (Russell et al. 2009) C stocks that might otherwise increase, suggesting that this methodology may, if anything, promote soil C sequestration. We nevertheless make no such claim.

Therefore, the soil C pool is deemed de minimis and is excluded from methodology accounting.

APPENDIX C – Calculating baseline N fertilizer rate

Approach 1

The baseline fertilizer N rate is determined from the project proponents management records for at least the previous five years (monoculture) or six years (e.g., three cycles of a two crop rotation, or two cycles of a three crop rotation) prior to the proposed project implementation year.

Management records from which baseline fertilizer N rate can be directly determined are required. Examples of these include synthetic fertilizer purchase and application rate records, as well as manure application rate and manure N content history.

Determination of the baseline N_2O emissions are based on an average of the previous N rate applications for the specific crop(s).

Worked example - Calculating baseline fertilizer N rate for corn in a corn–soybean rotation

For a proposed project beginning in 2011, a producer (project proponent) has applied the following fertilizer N rates to a corn–soybean rotation in the previous 6 years (3 rotations, Table C1).

Table C1. Fertilizer N rates applied to a corn–soybean rotation (2005 – 2010).

Year	Crop/Rotation	Synthetic Fertilizer N rate (kg N ha^{-1} yr^{-1})	Organic Fertilizer N rate (kg N ha^{-1} yr^{-1})	Total Fertilizer N rate (kg N ha^{-1} yr^{-1})
2005	Corn	180	20	200
2006	Soybean	0	10	10
2007	Corn	160	30	190
2008	Soybean	20	0	20
2009	Corn	190	20	210
2010	Soybean	0	0	0
2005–2010 Average	Soybean	= (0+20+0)/3 =6.7	= (10+0+0)/3 = 3.3	= (10+20+0)/3 = 10
2005–2010 Average	Corn	= (180+160+190)/3 ≈ 177	= (20+30+20)/3 ≈ 23	= (200+190+210)/3 = 200
2005–2010 Average	Corn–Soybean	= (180+0+160+20+190+0)/6 ≈ 92	= (20+10+30+0+20+0)/6 ≈ 13	= (200+10+190+20+210+0)/6 = 105

The baseline fertilizer N rate for a corn crop in the proposed project to be planted in 2011 is calculated from the average of the total fertilizer N rate applied to the previous 3 corn crops during the previous 6 years, i.e., = (200 + 190 + 210)/3 = 200 kg N ha^{-1} yr^{-1}. Reductions from this baseline 'common practice' rate are considered additional and are credited.

N.B. The baseline synthetic and organic fertilizer N rate (Table C1) in each year (t), are calculated from:

($M_{B\ SF,\ t}$ * $NC_{B\ SF}$) and ($M_{B\ OF,\ t}$ * $NC_{B\ OF}$), respectively,

Where:

$M_{B\ SF,\ t}$	Baseline N containing synthetic fertilizer applied, Mg ha^{-1} in year t;
$M_{B\ OF,\ t}$	Baseline N containing organic fertilizer applied, Mg ha^{-1} in year t;
$NC_{B\ SF}$	Nitrogen content of baseline synthetic fertilizer applied g N $(100g\ fertilizer)^{-1}$;
$NC_{B\ OF}$	Nitrogen content of baseline organic fertilizer applied g N $(100g\ fertilizer)^{-1}$;

Approach 2

If the baseline fertilizer N rate cannot be determined from project proponent records (Approach 1), then Approach 2 is used. With Approach 2, the baseline fertilizer N rate is calculated from crop yield data at the county level (available from the United States Department of Agriculture – National Agricultural Statistics Service (USDA – NASS)) and equations for determining fertilizer N rate recommendations based on yield goal estimates (found in e.g., state department of agriculture and university agricultural extension documents). The baseline fertilizer N rate value calculated using Approach 2 represents the product of the mass and the N content of the synthetic N containing fertilizer, i.e., $M_{B\ SF,\ t}$ * $NC_{B\ SF}$. Approach 2 is not applicable for the calculation of the baseline organic fertilizer N rate, therefore the value of $F_{B\ ON,\ t} = 0$.

Worked example - Calculating baseline fertilizer N rate for corn in a corn–soybean rotation in Tuscola County, Michigan

From the methodology "During the project crediting period, adherence to 'Best Management Practices' (BMPs) for the management of synthetic and organic N fertilizer at the project site is required.

For a project developer based in Michigan, the Michigan Department of Agriculture publication Generally Accepted Agricultural Management Practices (GAAMP) for Nutrient Utilization, (2013, or most recent version) is consulted (Michigan Department of Agriculture 2013). This publication recommends the Michigan State University (MSU) Extension Bulletin E–2904 – Nutrient Recommendations for Field Crops in Michigan (Warncke et al. 2004), for selecting the appropriate rate of N fertilizer for corn.

From Extension Bulletin E–2904 the equation for calculating the N rate (lb N $acre^{-1}$) recommendation for a corn (grain) crop planted in rotation with soybean in mineral soil is given by:

$$N\ rate = (1.36 * YG_t) - 27 - NC \quad (C1)$$

Where:

YG_t	Yield goal of crop in year t, to which recommended N rate will be applied, bushel $acre^{-1}$;

NC Nitrogen credit from previous soybean crop, lb N $acre^{-1}$.

In Extension Bulletin E–2904 soybean is given an N credit of 30 lb N $acre^{-1}$.

To calculate the predicted future corn yield the following equation is used:

$$YG_t = 1.05 * [(Y_{t-2} + Y_{t-4} + Y_{t-6}) / 3] \quad (C2)$$

Where:

Y_t = Project start date (year)

Y_{t-n} = Average county yield of crop in years 2, 4, and 6 prior to project adoption.

The approach of taking previous year's yield data and multiplying by 105% (1.05) in order to calculate the yield goal for the forthcoming crop is a common and conservative practice for producers. The approach is consistent with typical recommendations from university extension and agronomic organizations. Documentation outlining this approach is found for example in Fertilizer Suggestions for Corn – G174, University of Nebraska, Lincoln (Shapiro et al. 2003), and The Illinois Council on Best Management Practices (2001).

For Approach 2, the previous years yield data is determined from interrogation of the USDA – NASS web pages (Figures C1 and C2, http://www.nass.usda.gov).

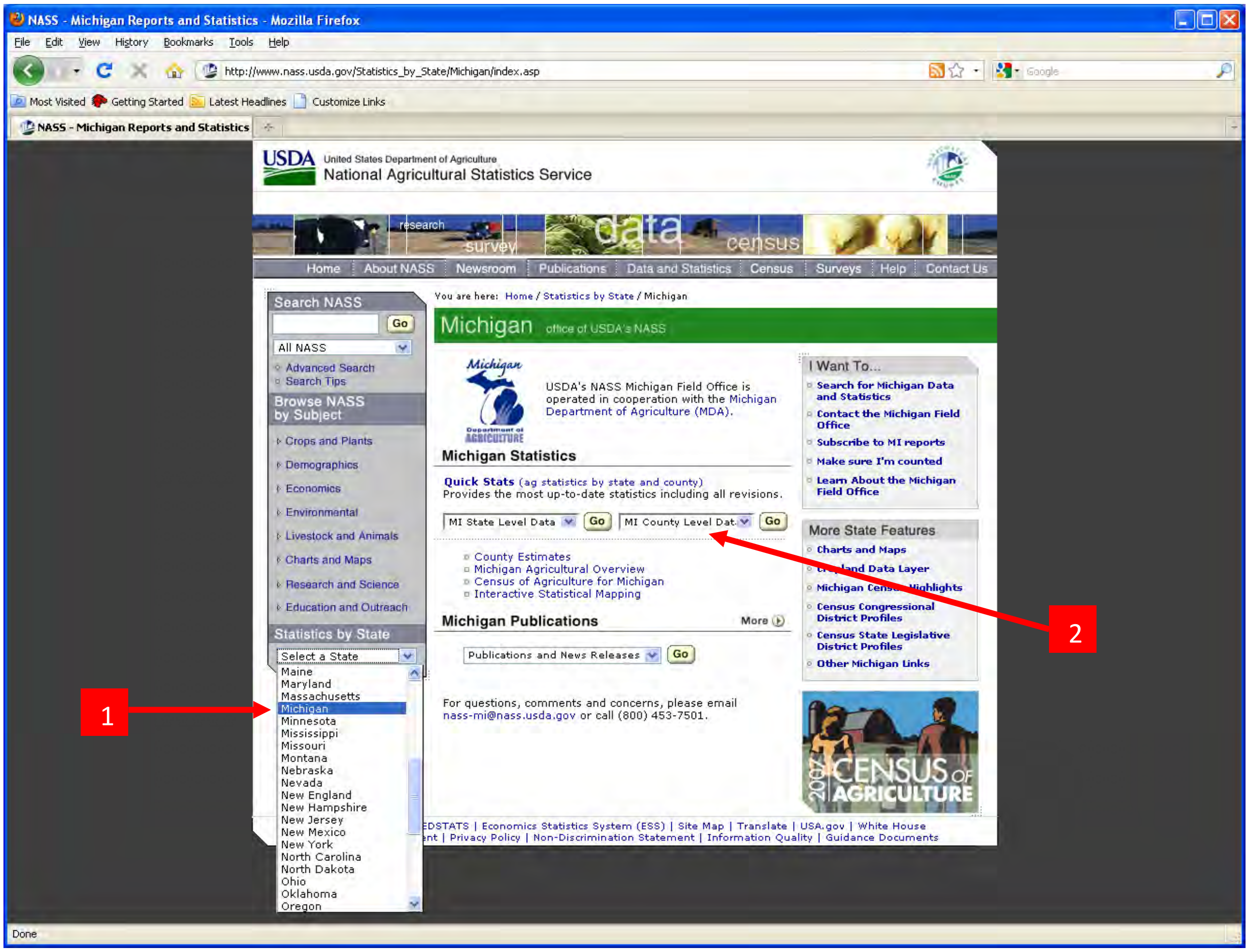

Figure C1. USDA – NASS screen shot showing selection menus for State (1), and County (2) level data inquiry.

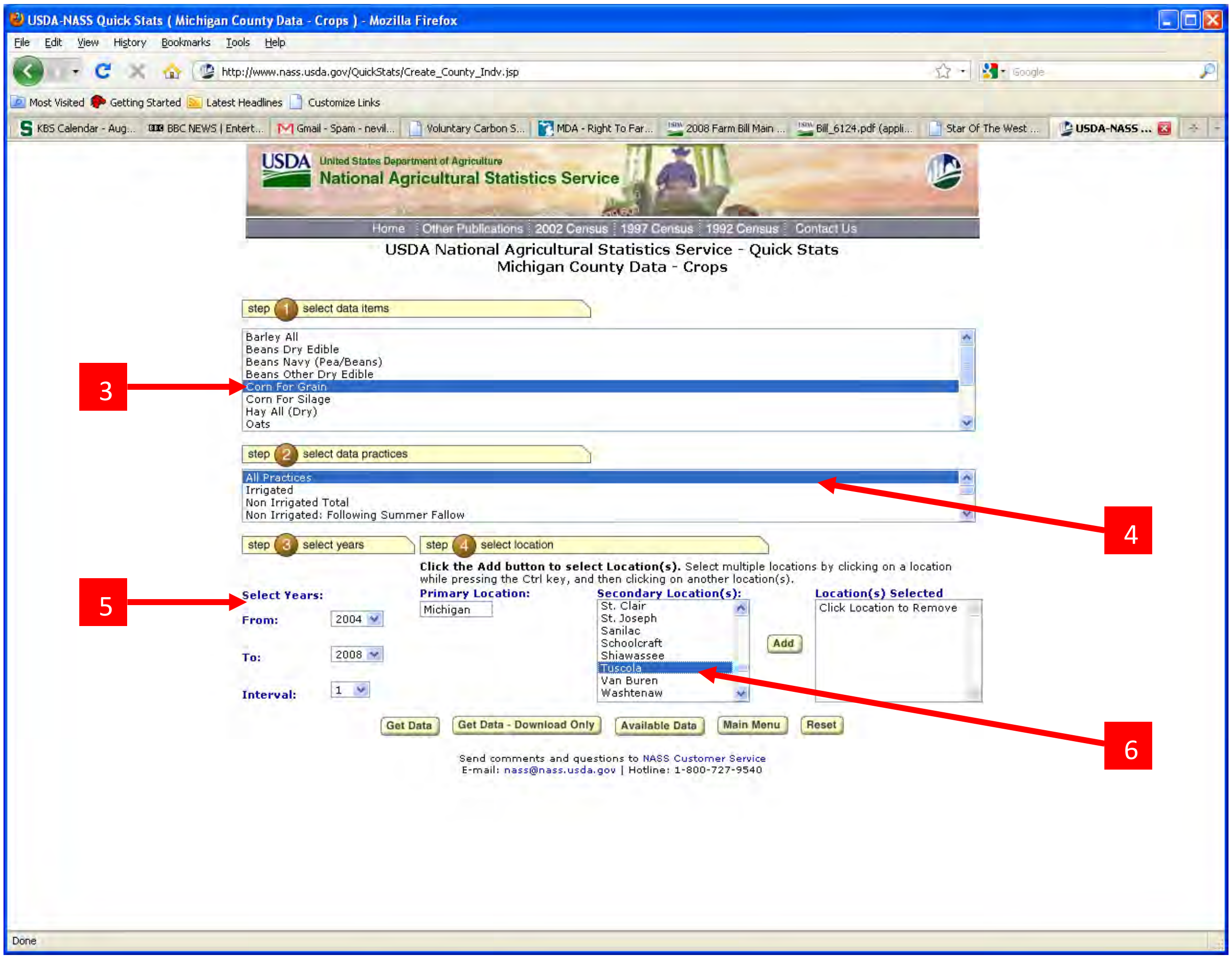

Figure C2. USDA – NASS screen shot showing selection menus for crop (3), practice (4), years (5) and County (6).

Data is downloaded as .csv files from which average yield data can be calculated (Table C2).

Table C2. Area planted, area harvested, yield data and total county production for corn (grain) in Tuscola county Michigan, for years 2005 through 2010.

	2005	2006	2007	2008	2009	2010
Yield (bushel acre^{-1})	148	154	134	174	164	148

The use of crop yield data from USDA – NASS must be consistent with the crop rotation history of the proposed project site(s). In this example a project field has had corn grown in rotation with soybean for at least the last six years (2005 – 2010, starting with corn). The calculation therefore must use USDA – NASS data for corn yield from 2005, 2007 and 2009 for a project start date of 2011. Using equation C2, we can calculate the yield goal for corn in 2011 (year t) as follows:

$$YG_t = 1.05 * [(148 + 134 + 164) / (3)]$$

$$= 156.1 \text{ bushel acre}^{-1}$$

From equation C1 the fertilizer N rate recommendation for corn (grain) in Michigan:

$$= (1.36 * 156.1) - 27 - 30$$

$$= 155.3 \text{ lb N acre}^{-1}$$

For conversion from non SI (lb N acre-1) to SI (kg N ha-1) units, the value is multiplied by 1.12 (a conversion factor accepted by the American Society of Agronomy (ASA), the Crop Science Society of America (CSSA), and the Soil Science Society of America (SSSA).

http://www.soils.org/files/publications/journals-sitable-coversions.pdf.

The fertilizer N rate recommendation for corn (grain) is then:

$$= 174.0 \text{ kg N ha}^{-1}$$

This value is considered the baseline fertilizer N rate for corn (grain) in a corn–soybean rotation for any proposed project site situated in the county of Tuscola, Michigan that had a project start date in 2011.

Depending on the proposed project details, similar equations for crops in other states can be utilized.

Note, as with Approach 1 the BAU baseline N fertilizer rate initially calculated remains fixed for the crediting period.

Information on the use of nitrogen credits from organic N fertilizer (manure) when Approach 2 is used is given in Appendix E.

APPENDIX D – Regulatory Surplus

To demonstrate additionality a project will need to pass a regulatory surplus test.

Project developers will pass this test if 'there is no mandatory law, statute or other regulatory framework in place at the local, state, or federal level, requiring producers to reduce fertilizer N input rate below that of a business–as–usual, i.e., common–practice scenario.'

The following paragraphs present some information and examples of regulations that deal with fertilizers and their application. The following is not meant to be an exhaustive list of regulations. Project developers must conduct a complete evaluation of federal, state and local regulations applicable to fertilizer use in the selected project location as part of the additionality assessment.

There is no Federal fertilizer statute and fertilizers are regulated under the individual States' authority. The Federal government does not regulate fertilizer directly however, there are regulations concerning the production, use and disposal of hazardous materials, drinking and surface water contamination and air pollution that are indirectly relevant to the use of hazardous materials in fertilizers and the application of fertilizers to land.

Below is a list of regulations at the Federal and State (Michigan) level that deal in some part with practices relating to synthetic and organic N fertilizer management in the agricultural sector.

Federal Regulations

The Food, Conservation, and Energy Act (2008)

The Military Munitions Rule (1997)

The Water Quality Amendment Act (1987)

The Superfund Amendments and Reauthorization Act (SARA) (1986)

Resource Conservation and Recovery Act of 1976 (RCRA) Statute - Solid Waste Disposal, Title 42, Chap. 82, Subchapter III - Hazardous Waste Management

The Federal Water Pollution Control Act (1972)

Hazardous Waste Regulation, 40 CFR, Part 503, Standards for the Use or Disposal of Sewage Sludge

The Occupational Safety and Health Administration (OSHA) Hazard Communication Standard (29 CFR 1910.1200)

State Regulations

Each state in the US has its own fertilizer regulatory program. State regulations for fertilizers are generally developed and administered by State agriculture departments. Such regulations primarily address efficacy claims and composition statements of the active ingredients displayed on fertilizer labels. Most States have fertilizer regulations similar to that of the Association of American Plant Food Control Officials (AAPFCO) model Uniform State Fertilizer Bill.

The Uniform State Fertilizer Bill is a model bill providing the legal authority to regulate the registration, packaging, labeling, sale, storage, distribution, use and application of fertilizer and fertilizer materials. There are specific requirements for the accurate and meaningful labeling of fertilizers, including terms and definitions, and regulations for the storage requirements for bulk fluid and dry fertilizers.

Other AAPFCO Uniform Bills which may relate to fertilizer N application include the Uniform Soil Amendment Bill, the Model Agricultural Liming Materials Bill, the Model Chemigation Bill and the Uniform State Ammonia Bill.

Example: Michigan State Regulations

Below are state level regulations indirectly relating to fertilizer N management as outlined in the Michigan Department of Agriculture Generally Accepted Agricultural and Management Practices (GAAMP) for Nutrient Utilization publication (Michigan Department of Agriculture, 2013).

These regulations apply to 'a person applying, distributing, and storing fertilizer or organic materials in Michigan' who 'must comply with the relevant state and federal laws and regulations promulgated under these statutes, including but not limited to':

Public Act 451: Natural Resources and Environmental Protection Act of 1994

Public Act 346: Commercial Drivers' License Law of 1988

Public Act 368: Michigan Public Health Code of 1978

Public Act 399: State of Michigan Safe Drinking Water Act of 1976

Public Act 154: Michigan Occupational Safety and Health Act (MIOSHA) of 1974

Public Act 162: Michigan Liming Materials Law of 1955

Further useful information regarding fertilizer regulations can be found at the Safe Fertilizer Information Institute (http://saffii.com/uslaw.aspx).

APPENDIX E – Business as Usual (BAU) practice for N fertilizer application and justification for Approach 2

In using this methodology, project proponents must exceed a performance benchmark. Project proponents exceed the performance benchmark by reducing their N fertilizer rate below the BAU rate, which is also the baseline value for N fertilizer rate for the proposed project. This baseline scenario equates the N fertilizer application with the widespread and general practice of producers to apply N fertilizer rates based upon recommendations derived from yield goal estimates. Reductions in N fertilizer rate below the baseline site specific value (Approach 1) or below the baseline value in the county where the project is to be conducted (Approach 2) will result in a project exceeding the performance benchmark. Both Approach 1 and 2, used to establish the project baseline, operate on the principle that a reduction in N fertilizer rate below the baseline results in a predictable, concomitant reduction in N_2O emissions. Project additionality is achieved through a reduction in N rate below the baseline scenario, such that 'new' N_2O emissions are prevented from entering the atmosphere. These avoided emissions occur immediately, are irreversible, and are permanent.

Evidence for the wide-scale historic, continued, and extensive use of the yield goal approach as the baseline (BAU) scenario, and therefore its legitimacy as a performance benchmark for testing additionality in crop-based agriculture, is given below.

Justification of the yield goal approach as a BAU baseline scenario

Since the 1970s it has been common practice throughout the NCR and the conterminous US in general for producers to apply rates of N fertilizer based on recommendations derived from yield goal estimates (e.g., Fixen, 2006; Shapiro et al. 2003; Warncke et al. 2004). The agricultural departments of land grant universities, state and federal agricultural organizations continue to endorse yield-goal N fertilizer rate recommendations (e.g., Michigan Department of Agriculture, 2013, USDA – NRCS, 2011; 2012). For example, the recently updated (July 2012) USDA – NRCS Conservation Effects Assessment Project (CEAP) states:

"Nutrient management systems have four basic criteria for application of commercial fertilizers and manure. 1. *Apply nutrients at the appropriate rate based on soil and plant tissue analyses and realistic yield goals.*"

All these organizations represent a common source of external information that provides advice directly or indirectly to producers. This network serves as the foundation for producer BAU practice in the NCR and beyond, constituting a sector-wide approach for calculating baseline N fertilizer rates and, by extension, emissions of N_2O.

Despite this, very few studies have quantitatively examined the numerous factors and their complex interactions and impact on a farmers' decision of how much N fertilizer to apply to a crop. Those that have done so indicate that the majority of farmers rely heavily on their own experience, as well as on advice from fertilizer dealers. For example, using USDA data Ribaudo et al. (2011) found that 72% of growers base their N fertilizer application decision on 'routine practice', and from a recent survey sent to 1000 farmers in SW Michigan, Stuart et al. (2012) found that almost all respondents receive information from fertilizer and seed dealers on how to determine their N fertilizer application rates; for 55% this represents the most important source of information; only 18% used university recommendations as their most important source.

Important though these data are, they do not report the dealers' rationale or calculations for the advice given. This data is scarce. However, university recommendations are based on yield goal calculations, and in the MI survey, Stuart et al. (2012) found that 72% of commercial corn farmers use a simple yield-goal calculation to derive their N rate. This value is identical to the percentage of growers who base their N fertilizer application decision on routine practice (Ribaudo et al. 2011). The remaining 28% appear to use some combination of other farmers, private consultants, magazine articles, and other informal sources unlikely to be as conservative (Stuart et al. 2012).

From the MI survey, of the farmers who fertilized using simple N-to-yield-goal ratios (lbs N per bushel of corn) the percentages who reported a particular ratio were 5 (>1.3), 21 (1.1 to 1.3), 55 (0.8 to 1), and 19 (<0.8).

If we use the five year average corn grain yield for MI between 2007 and 2011 of 143 bushels per acre, we can estimate N rate applications (kg N ha^{-1}) for these groups as >208, 176 to 208, 128 to 160, and <128, respectively. Extrapolating these trends nationally where average corn grain yield between 2007 and 2011 was 154 bushels per acre, we get >224, 190 to 224, 138 to 172, and <138, respectively.

It is not known whether respondents to the MI survey took into account N contributions (N credits) from other sources such as prior leguminous crops or manure. If not (as is likely), then on average there would be an increased percentage of respondents placed in the higher ratios (1.1 to 1.3, and > 1.3). In the survey, nearly half of the respondents used both commercial synthetic N fertilizers and manure on their crops (none used manure N only – consistent with national data, e.g., Ribaudo et al. 2011). However, nearly 60% never tested their manure for N content and 64% never kept any records if they did. This suggests that the N rates were under-reported, and therefore the respondent's N-to-yield-goal ratio underestimated. Under-reporting of N rate application has been reported elsewhere. For example, data from California across a wide range of crops indicate that on average producers apply approximately 38 lbs N per acre (~42 kg N per hectare) more than they report (Rosenstock et al. 2013). Data from Ribaudo et al. (2011) indicates that when farmers use both manure and commercial fertilizer, they apply on average 28% higher N rates to their crops, when compared to farmers who apply only synthetic N fertilizers. This is despite the recommendation to farmers who use both N sources to apply 10% less N than to those who use only synthetic N.

Despite decades-old concerns and quantitative evidence that yield goal-based recommendations are inaccurate (e.g., Lory and Scharf 2003) and too liberal for recommending N fertilizer rate, the practice is still widely recommended and followed. This inevitably leads to applications of N fertilizer in excess of crop requirements, principally as a result of unrealistic yield goal estimates (e.g., Vanotti and Bundy 1994). Furthermore, to maintain viable operations, farmers may manage temporal variability in weather and soil N by over-applying N to protect against downside risk (i.e., use an 'insurance' N application rate) (Sheriff, 2005; Babcock, 1992; Babcock and Blackmer, 1992). Additionally, farmers may take a 'safety net' approach to maximize economic returns by setting an optimistic yield goal for a given field based on an optimum weather year to ensure that the needed amount of N for maximum yields is available (Schepers et al., 1986; Bock and Hergert, 1991). Thus, during the years in which weather is not optimal for maximizing yields, N will be over-applied from an agronomic standpoint. By definition, optimal conditions are infrequent, so farmers over-fertilize crops in most years. It is therefore safe to conclude that reductions in N rate below those determined by yield-goal based calculations (i.e., the BAU baseline scenario) can be implemented to reduce the amount of excess N in cropland agriculture, thereby decreasing its N_2O burden without reducing crop productivity.

A regional approach to optimize crop yield has recently been developed that utilizes historical and current N fertilizer rate research data from field trials to determine economically profitable N inputs, expressed as a range of N rates around a maximum return to N (MRTN) at different N fertilizer and crop prices (Iowa State University Agronomy Extension 2004). The US Midwest states currently providing data for this approach are Iowa, Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. Producers with relevant cropping systems in these states (and other states that may subsequently become involved) may wish to adopt a N fertilizer rate for the project within the economically profitable N rate range calculated, using this approach (Millar et al. 2010). Use of MRTN to reduce N rate use is not required, however – other methods may be used to reduce rates to better match crop needs, including the use of improved fertilizer application timing, fertilizer formulations, cover-crop N capture, or any of a number of other practices known to better match N fertilizer input to crop N needs than BAU approaches (Robertson and Vitousek 2009).

Justification for Approach 2 for determining the baseline scenario

If the baseline fertilizer N rate for a specific crop cannot be established from project proponent records (Approach 1), then Approach 2 can be used. With Approach 2, baseline N fertilizer rate is calculated from crop yield data at the county level, available from United States Department of Agriculture – National Agricultural Statistics Service (USDA – NASS), and equations for determining N fertilizer rate recommendations based on yield goal estimates (e.g., found in state department of agriculture and land grant university agriculture department documents).

The use of crop yield data from USDA – NASS must be consistent with the crop rotation history of the proposed project site. For example, a project field in which corn has been grown in alternate years with soybean for the last six years (2006 – 2011; starting with corn) must use USDA – NASS data for corn yield for the relevant county from 2006, 2008 and 2010 for a project start date of 2012. This requirement reduces the uncertainty in baseline calculation, as county crop yield records for an individual year reflect the prevailing environmental and economic conditions at that time. This requirement also reduces the potential for 'gaming' as project proponents cannot select historical data that might have the effect of artificially increasing the baseline.

The rationale for why Approach 2 is conservative, and discussion on the trade-offs between false positives (the crediting of activities that are not additional) and false negatives (the exclusion of activities that are additional) in relation to Approach 2 calculations are presented below.

The use of Approach 2 will typically underestimate baseline N inputs due to two major factors: 1. the use of county level crop yield data sets that include non-commercial and small-scale farming operations that tend to have lower productivity than large scale operations; and, 2. the compulsory inclusion of N credits from organic fertilizer (manure) applications in yield goal equations as an artificial means to lower baseline N rate recommendations, and therefore baseline N_2O emissions. Overall, this underestimation will bias the award of offset credits towards a false negative outcome (the exclusion of activities that are additional).

The use of county level crop yield data

The county level crop yield data from USDA – NASS required to back-calculate baseline N fertilizer rates using Approach 2 includes data collected through the annual County Agricultural Production Survey (CAPS) and the Census of Agriculture (COA) conducted every five years.

The CAPS provides data needed to estimate production of crops at the county level for state and federal programs, and is conducted in 44 states with all counties in these states represented in the sampling. The target population is all farms and ranches in each state, with each state developing its own data collection strategy, typically a mail survey with second mailings or a telephone follow-up to ensure adequate coverage for each county. The average, annual county yield data therefore inherently covers crops to which only synthetic N fertilizer and both synthetic and organic N fertilizers have been applied.

As defined by the CAPS and COA, a farm is any place from which $1,000 or more of agricultural products are normally produced and sold during the surveyed year. Between 2002 and 2007 (latest available) the COA found that the number of farms with sales of less than $1,000 increased by 118,000, with most of the growth in US farm numbers coming from small operations. In 2007, 60% of total US agricultural sales came from farms where annual sales were less than $10,000. Small farms account for 91% of all farms in the US with a large percentage of these farms specializing in grain production.

Data linking farm size to crop yields is limited, but a specially conducted USDA ARMS survey on the cost of production of corn in 1996 found that part-time farmers and small farm operations tended to have lower production efficiency, higher corn production costs per bushel and lower than average yields (Foreman, 2001). Therefore the link between lower yields and small farm size and the continuing trend for increasing numbers of part-time farmers and small farm operations in the US provides evidence that the average county yield reported will tend to underestimate the yields obtainable from larger, more efficient operators who will most likely constitute the majority of project developers, at least in the short-term. This will result in lower county-level yields' biasing the fertilizer N estimate for the larger growers towards lower N application rates (a lower county-level yield will result in a lower predicted baseline N rate for those farmers with higher yields).

The compulsory inclusion of N credits from manure applications

The most common form of organic N applied to cropland in the US is animal manure. Most of the US cropland (~ 70%) receiving manure is used to grow corn (Ribaudo et al. 2011). Nationwide, about 14% of all N fertilized corn acres (~10% for all crops) are treated with both commercial synthetic N and manure N. Nationally, this amounts to approximately 13 million acres of corn based upon 2012 planting data (USDA – NASS). USDA ARMS data provides evidence that when used; manure is associated with over application of N. For example, with farmers who used a soil or tissue test as a means to estimate their N need, the average N application rate by those who used both synthetic and manure N was 175 lbs N per acre, compared to 136 lbs N per acre for growers who used synthetic N only. As noted earlier, this was despite a 10% lower recommendation for fields receiving both N sources compared to those receiving only a commercial synthetic N source (Ribaudo et al. 2011).

When using Approach 2, project proponents will include a nitrogen credit from organic N fertilizer (manure). The inclusion of an N credit for organic N fertilizer in some or all of the baseline years for which an estimate of the N fertilizer rate is required will, in effect, act to reduce the calculated average baseline N rate and therefore baseline N_2O emissions. Irrespective of the actual use of organic N fertilizers during the baseline period, and whether this is verifiable in part or not, this procedure will act to lower the baseline N_2O emissions of the project field when compared to a scenario when no N credit for organic N fertilizer is applied. This approach is conservative.

Seven hypothetical scenarios (some more likely than others) relating to document and data availability are presented below, along with the rationale for the required N credit associated with them:

1. No records are available to verify the timing (i.e., the year or growing season), amount, or N content of the organic N fertilizer;

2. Records are available that verify the timing, but not the amount or N content of the organic N fertilizer

3. Records are available that verify the timing, and amount, but not the N content of the organic N fertilizer

4. Records are available that verify the amount, but not the timing and N content of the organic N fertilizer

5. Records are available that verify the amount and timing, but not the N content of the organic N fertilizer.

6. Records are available that verify the N content, but not the amount or timing of the organic N fertilizer

7. Records are available that verify the amount and N content, but not the timing of the organic N fertilizer

In six of these seven cases, at least one of the three requirements is available to determine the organic N fertilizer applied during the entire baseline period. In three of these cases, two of the three requirements are available. If all three requirements regarding data were met then the project would use Approach 1 for calculation of the baseline N rate for organic fertilizer.

The rationale behind the approach matches an increased availability of records with a decreased N credit for organic N fertilizer, and therefore an increased baseline N rate, and baseline N_2O emissions. In effect the approach 'rewards' more comprehensive record keeping, as an increased baseline N rate will potentially allow for larger decreases in N rate during the project period and therefore greater financial payback through the award of offset credits. Note that all individual requirements are weighted equally.

There is therefore no incentive (financial or otherwise) to deliberately withhold documentary evidence establishing the application of organic (or indeed synthetic) N fertilizer during the baseline period. Doing so would act to artificially reduce the value of the baseline N rate (and therefore baseline N_2O emissions), thereby reducing: 1) the likelihood that an N rate reduction could take place at all; and 2) the magnitude of that reduction, without a producer's incurring a yield penalty or substantially increasing the risk of doing so.

Note that if records of the timing of organic fertilizer application (i.e., the year or growing season [but not necessarily the exact date]) are absent, but the amount and / or N content are available then it will be assumed that organic fertilizer has been applied in all relevant cropping cycles previous to the project crop in the project field during the baseline period.

Scenario crediting

The quantitative basis for applying the specific N credit for organic fertilizer (manure) is derived from the recent USDA ERS report "Nitrogen in Agricultural Systems: Implications for Conservation Policy" (Ribaudo et al. 2011). Using national Agricultural Resource Management Survey (ARMS) data, the report found that farmers who used both synthetic fertilizer and manure (all sources), applied on average 90 lbs N per acre from the manure.

So:

For scenario 1 where none of the three data requirements are available, the nitrogen credit from organic fertilizer will be:

90 * 1.5 = 145 lbs N per acre

= 162 kg N ha^{-1}

For scenarios where one of the three requirements is available (scenarios 2, 4, and 6), the nitrogen credit from organic fertilizer will be:

90 * 1.2 = 108 lbs N per acre

= 121 kg N ha^{-1}

For scenarios where two of the three requirements are available (scenarios 3, 5, and 7, the nitrogen credit from organic fertilizer will be:

90 * 1.0 = 90 lbs N per acre

= 101 kg N ha^{-1}

Using the worked example given for Approach 2 in Appendix C, where the N rate (lb N $acre^{-1}$) is calculated as:

$$N\ rate = (1.36 * YG_t) - 27 - NC \quad (E1)$$

Where:

YG_t = 156.1 bushel $acre^{-1}$

If we assume that two of the three data requirements are available from records, the N credit equals the sum of the N credit from the previous soybean crop (30 lbs N per acre) and the previous manure applications (90 lbs N per acre).

Therefore:

N rate = (1.36 * 156.1) - 27 - (30 + 90)

= 65 lb N $acre^{-1}$

= 73 kg N ha^{-1}

APPENDIX F - Default factors

The default (Tier 1) values used in the methodology for calculating direct and indirect emissions of N_2O from the baseline and project scenarios are taken from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Volume 4, Chapter 11).

The terminology of the factors used in this methodology differs from that used in the IPCC guidelines, but the factors are equivalent in value and usage.

The IPCC uncertainty ranges for each factor or fraction can be considered conservative with respect to their application to agricultural soils, as their use in IPCC Guidelines is applicable to a wider environmental coverage, i.e., managed soils, including forests and grasslands as well as agriculture.

Table F1. Default factors used to estimate direct and indirect emissions of N_2O in the methodology.

N_2O Emissions	Methodology factor	IPCC factor	Default value	Uncertainty range
Direct	EF_{BDM1}, EF_{PDM1}	EF_1	0.010	0.003 - 0.03
Indirect	EF_{BIV}, EF_{PIV}	EF_4	0.010	0.002 - 0.05
Indirect	EF_{BIL}, EF_{PIL}	EF_5	0.0075	0.0005 - .025
Direct/Indirect	$Frac_{GASF}$	$Frac_{GASF}$	0.10	0.03 - 0.3
Direct/Indirect	$Frac_{GASM}$	$Frac_{GASM}$	0.20	0.05 - 0.5
Direct/Indirect	$Frac_{LEACH}$	$Frac_{LEACH}$	0.30	0.1 - 0.8

Conversion of N_2O–N to N_2O

Conversion of N_2O–N (the mass of the nitrogen component of the nitrous oxide molecule emitted) to N_2O for reporting emission reductions in units of CO_2e is performed by multiplication of the ratio of the molecular weight of N_2O to the atomic weight of the two N atoms in the N_2O molecule:

$$N_2O = N_2O\text{–}N * 44/28$$

Global Warming Potential of N_2O

The GWP value of 310 for N_2O used in the methodology is the 100-year value proposed in the Intergovernmental Panel on Climate Change Second Assessment Report (SAR).

The value of 310 is the direct GWP for one molecule of N_2O on a mass basis for a 100 year time horizon, relative to one molecule of CO_2, which is ascribed a value of 1 by convention. This means that a molecule of contemporary N_2O released to the atmosphere will have 310 times the radiative impact of a molecule of CO_2 released at the same time. The conversion can be represented as:

$$N_2O_{GWP} = 310,\ Mg\ CO_2e\ (Mg\ N_2O)^{-1}$$

APPENDIX G – Background research on method 2 for estimating emissions

In the North Central Region (NCR), direct emissions of N_2O for baseline and project scenarios in corn-based, row-crop rotations can be calculated using Method 2. Method 2 uses an emissions factor determined from multi–year field studies conducted in Michigan. This emissions factor is consistent with IPCC Tier 2 methodological guidelines and in this methodology assigned the terms EF_{BDM2} and EF_{PDM2} for baseline and project emission calculations, respectively.

Full details of study sites, sampling, data analysis, results, and other information are in Hoben et al. (2011), and at http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2010.02349.x/suppinfo.

The uncertainty assessment for emissions reductions, including the derivation of the Tier 2 emissions factor are detailed below.

Overview

Previous research conducted by McSwiney and Robertson (2005), and more recently by Hoben et al. (2011) and Millar et al. (2013) show that N_2O emissions can increase exponentially with increasing N fertilizer rate, particularly at high rates that exceed the crop N uptake capacity.

These unique field studies in the North Central Region (NCR) specifically investigated long–term N_2O emission responses to a large number of N fertilizer rate treatments in row–crop agriculture. The large number of N rates and the small increments between them allow better resolution of the shape of the relationship between N rate and N_2O emissions.

The producer sites used in the development of the Tier 2 approach (Hoben et al. 2011) encompassed a wide range of soil type, texture, and grain yield that were comparable and broadly representative of commercial corn crop rotations and conditions throughout the NCR. During the study years, the sites experienced a wide range of environmental conditions throughout the growing season. In years with normal precipitation, crop yields at these sites are typical of the NCR as a whole (Smith et al. 2007). The N rates employed in Hoben et al. (2011) also are within the range commonly required for optimum corn-grain production and recommended for the US Midwest (Sawyer et al., 2006; Vitosh et al., 1995).

The non–linearity of N_2O emissions has significant consequences when comparing N_2O emissions reductions with the IPCC Tier 1 approach. An identical N fertilizer rate reduction will result in a significantly smaller reduction in N_2O emissions when the Tier 1 emission factor is used in calculations, when compared to the Tier 2 emission factor. The increasing divergence of N_2O emissions between Tier 1 and Tier 2 approaches, particularly at higher N rates, helps incentivize the reduction in N rate. Millar et al (2010) show an example of this.

Uncertainty assessment

Methodologies and procedures adopted to calculate emissions of N_2O have been refined over many years, and are conservative in nature. Here we outline assumptions, parameters and procedures that relate to uncertainty in N_2O emissions in the methodology. We focus on the derivation of the regional NCR emissions factor used in equation (6) and (15) in sections 8.1 and 8.2, respectively. More detailed information on field-sampling and laboratory analytical techniques is given in Hoben et al. (2011).

Appendix F (Table FI) provides information on uncertainty ranges for IPCC Tier 1 emissions factors for direct and indirect N_2O emissions and other factors used in the methodology. Use of these IPCC emissions factors is universally accepted as a mechanism for calculating N_2O emissions – they are science driven and used in many currently accepted AFOLU methodologies for calculating N_2O emissions. Further details on these factors, their derivation and their robustness for use in N_2O

emissions calculations can also be found in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Revision Nov. 2008 - Chapter 11: N_2O Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application.

Application of N fertilizer

The methodology monitors five parameters during the project period. Four of these relate directly to the calculation of N rate applied at the project site. These are detailed along with their measurement and QA/QC procedures, in section 9.2 of the methodology.

All of these parameters are assumed to have negligible uncertainty.

Derivation of regional (NCR) emissions factor

Daily N_2O emissions

Values for daily N_2O emissions have negligible uncertainty; field and laboratory sampling and analytical techniques have been refined over many years to standardize methodologies and minimize analytical uncertainty. We used standard methods to measure daily emissions as described in Hoben et al. (2011).

Annual N_2O emissions

We determined total annual emissions by interpolating daily emissions between sampling days. This was carried out using linear interpolation – a broadly accepted mechanism in the scientific peer reviewed literature. In brief, the sum of the rate of N_2O emissions on two successive sampling days was divided by two (averaged), and this average rate was multiplied by the period (in days) between the two measurements, then added to the previous cumulative emissions total. This can be represented by:

$$C_B = C_A + [(D_A + D_B) / 2] * (B-A) \quad \text{(G1)}$$

Where:

C_B = Cumulative N_2O emission as of day B (g N_2O-N ha^{-1});
C_A = Cumulative N_2O emission as of day A (g N_2O-N ha^{-1});
D_A = Daily gas flux on day A (g N_2O-N ha^{-1} d^{-1});
D_B = Daily gas flux on day B (g N_2O-N ha^{-1} d^{-1});
B = Day of latest emissions measurement (day of year);
A = Day of previous emissions measurement (day of year).

Annual emissions (g N_2O-N ha^{-1} yr^{-1}) of N_2O for each field replicate were calculated from daily N_2O emissions (g N_2O-N ha^{-1} d^{-1}) measured in each block (4) at each N rate (6, including zero) at each site during the year for all site years (8), to give a total of 192 cumulative annual N_2O emissions data points (4 * 8 * 6). These individual cumulative annual emissions, calculated directly from daily N_2O emissions with negligible uncertainty, are also assumed to have negligible uncertainty.

The best-fit line that defines the mathematical relationship between N rate (kg N ha^{-1} yr^{-1}) and N_2O emissions (g N_2O-N ha^{-1} yr^{-1}) for all 192 data points is:

$$N_2O \text{ emissions} = 670 * \exp(0.0067 * \text{N rate}) \quad \text{(G2)}$$

Where, N rate is the equivalent of $F_{B\ SN,\ t} + F_{B\ ON,\ t}$ for baseline N input (equation [2]) and $F_{P\ SN,\ t + FP\ ON,\ t}$ for project N input (equation [11]).

The standard error (SE) associated with N_2O emissions, is:

N_2O emissions $_{(SE)}$ = 58 * exp (0.010 * N rate) (G3)

Figure G1 shows this relationship.

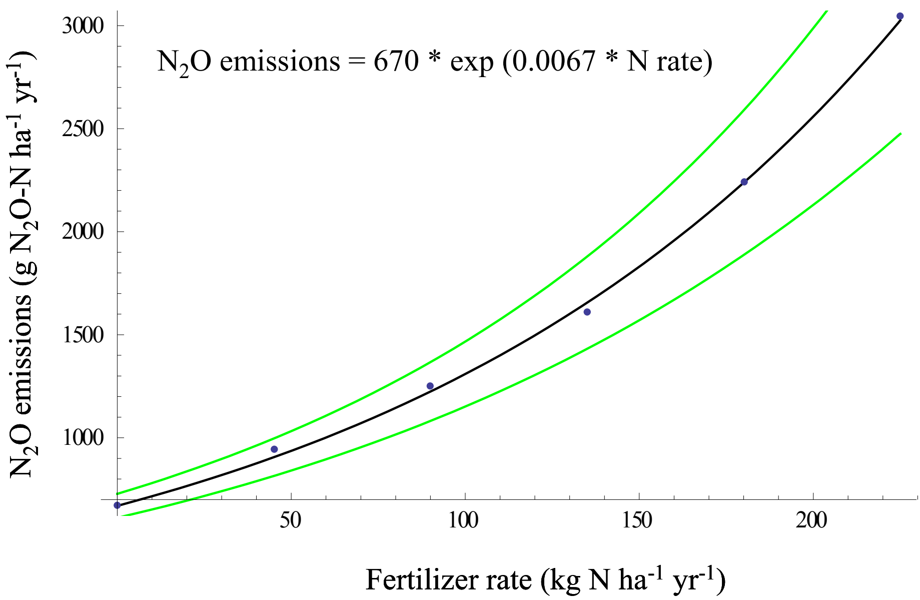

Figure G1. Relationship between N_2O emissions (g N_2O-N ha^{-1} yr^{-1}) and N fertilizer rate (kg N ha^{-1} yr^{-1}) for baseline and project N fertilizer rates (black line). Standard errors (± 58 * exp [0.010 * N rate]) are also shown (green lines). Calculated using Mathematica (v. 8, Wolfram Research Inc., 2011).

N_2O emissions reductions

Raw N_2O emissions reduction values were obtained by subtracting cumulative annual emissions of lower N application rates from cumulative annual emissions of higher N application rates (i.e., 0, 45, 90, 135, 180, and 225 kg N ha^{-1} yr^{-1}) within the same block, site, and year. This emissions difference was then divided by the difference in rate between the N rate pairs. Thus, we obtained 32 values (4 blocks * 8 site years) for the emission reductions for each of the 15 pairs (e.g., 45 → 0, 90→ 0, 90 → 45, etc.).

To best define the interpolation of the empirical data for emissions reductions - N_2O emissions $_{(RED)}$ - many types of function were tested, including linear and exponential functions with various parameter combinations. The function below (Equation [G4]) derived from equation [G2] above) was also tested.

N_2O emissions $_{(RED)}$ = 0.67 * {exp (6.7 * N_{Base}) - exp (6.7 * N_{Proj})} / (N_{Base} - N_{Proj}) (G4)

Where:

N_2O emissions $_{(RED)}$ = N_2O emissions reductions, g N_2O-N ha^{-1} yr^{-1};

N_{Base} = $F_{B\ SN,\ t}$ + $F_{B\ ON,\ t}$ baseline N input, Mg N ha^{-1} yr^{-1};

N_{Proj} = $F_{P\ SN,\ t}$ + $F_{P\ ON,\ t}$ project N input, Mg N ha^{-1} yr^{-1}.

Equation (G4) outperformed all linear functions and works as effectively as more complex exponential functions.

Emissions factors

The emissions factor for N_2O is defined as the fraction of N applied that is released as nitrogen in N_2O (N_2O-N) at a non-zero N rate minus the N_2O-N emitted at zero N rate.

The emissions factors for baseline and project calculations were obtained by dividing the reduction function (equation G4) by $1 * 10^6$ (to convert g N_2O-N / Mg N rate to Mg N_2O-N / Mg N rate). We then formatted the equation to compare baseline and project N rates to zero N rate. Therefore we have:

$$EF_{Base} = 6.7 * 10^{-4} * \exp([6.7 * N_{Base}] - 1) / N_{Base} \quad (G5)$$

$$EF_{Proj} = 6.7 * 10^{-4} * \exp([6.7 * N_{Proj}] - 1) / N_{Proj} \quad (G6)$$

Where:

EF_{Base} and EF_{Proj} are equivalent to EF_{BDM2} (Equation [6]) and EF_{PDM2} (equation [15]), respectively.

Emissions reduction uncertainty

The standard error equation (G3) is useful for describing uncertainty in annual emissions but cannot be used to accurately describe uncertainty for emissions reductions in the range of smaller N rate reductions (10 – 20 kg N ha^{-1} yr^{-1}).

Instead the 32 values (4 blocks * 8 site years) for the emission reductions for each of the 15 pairs (e.g., 45 → 0, 90→ 0, 90 → 45, etc.) were used to obtain variability of the mean using the Bootstrap method (Monte Carlo algorithm with case re-sampling, Mathematica – v. 8, Wolfram Research Inc., 2011).

For each pair of N fertilizer rate reductions a random sample of 32 baseline values was taken and replaced with a random sample of 32 project values to compute a mean reduction. This process was repeated 100,000 times and the overall standard error of the means were calculated.

The standard error of the means was then multiplied by 1.645 (the critical value of normal one-sided test at 95% confidence) and divided by the average emissions reduction to give the fraction of the average that is within the 95% confidence interval. These values plotted against N rate are represented by Equation (G7), which calculates the uncertainty associated with a reduction in N rate during the project period:

$$N_2O\ Emissions_{(RED\ UNC)} \quad [1 - \{0.63 * \exp(-40 * [N_{Proj}]^2)\}] * 100 \quad (G7)$$

Where:

N_2O Emissions $_{(RED\ UNC)}$	Uncertainty in N_2O emissions reductions associated with a reduction in N rate, %;
N_{Proj} =	$F_{P\ SN,\ t} + F_{P\ ON,\ t}$ project N input, Mg N ha^{-1} yr^{-1}.

Equation (G7) is identical to equation 19 in section 8.4 of this methodology.

Within the empirical N rate data range (0 – 225 kg N ha^{-1} yr^{-1}) the highest uncertainty was ~90%. There is no evidence to suggest that higher N rates would generate uncertainties above 100%, therefore the Gaussian function was used to constrain uncertainty below 100%.

Project proponents will use equation (G7) to calculate emissions reductions uncertainties (%) for a project. Confidence deductions as a result of uncertainty will be applied using the conservative factors specified in the CDM Meth Panel guidance on addressing uncertainty in its Thirty Second Meeting Report, Appendix 14 (Table G1).

Table G1: Conservativeness factors for emissions reductions based upon uncertainty at 95% confidence level.

Uncertainty range at 95% confidence level of project emissions reductions[§]	Conservativeness factor	Uncertainty deduction*
< ± 15%	1.000	0.000
> ± 15% ≤ ± 30%	0.943	0.057
> ± 30% ≤ ± 50%	0.893	0.107
> ± 50% ≤ ± 100%	0.836	0.164

[§] Uncertainty in emissions reductions does not exceed 100%. * Where uncertainty in emissions reductions is < ± 15%, no deductions will be applied. Uncertainty deduction (UNC) = (1 – Conservativeness factor).

APPENDIX H – Calculations to determine sufficiency of project N rate using N rate calculator

Below is a worked example demonstrating how the proposed N rate for a project area can be shown to be consistent with data output from an approved N rate calculator. In this example the Iowa State University corn nitrogen calculator is used (http://extension.agron.iastate.edu/soilfertility/nrate.aspx).

The Iowa State University corn nitrogen calculator calculates the profitable N rate range around the maximum return to nitrogen (MRTN) rate in continuous corn and corn-soybean rotations in seven states in the U.S. Midwest.

To show consistency, the total amount of N to be applied to the project area during a corn cropping season must be equal to or greater than 80% of the lowest estimate of the N rate range recommended for corn in the region in which it is grown.

Worked example for a proposed project in Michigan in a corn-soybean rotation

Calculating baseline fertilizer N rate for corn in a corn–soybean rotation
In the project area where corn will be grown, the farmer has previously applied N fertilizer to corn in rotation with soybean during 3 of the previous 6 years (Table H1). In this example the source of the N fertilizer is synthetic N but it could also have been organic N such as manure – the calculation would be the same.

Table H1. N fertilizer rates applied to corn in a corn–soybean rotation (2006 – 2011)

Year	Crop	Fertilizer N rate ($kg\ N\ ha^{-1}\ yr^{-1}$)
2006	Corn	140
2007	Soybean	0
2008	Corn	160
2009	Soybean	0
2010	Corn	150
2011	Soybean	0
2006–2011 Average	Corn	= (140+160+150)/3 = 150

The baseline fertilizer N rate for the corn crop in the proposed project to be planted in 2012 is calculated from the average of the total N fertilizer applied to the previous 3 corn crops during the previous 6 years, i.e. 150 kg N ha^{-1} yr^{-1}. Reductions from this baseline rate are considered additional and are credited.

The proposed project N rate for the corn crop to be planted in 2012 is 125 kg N ha^{-1}.

Demonstrating consistency with Iowa State University corn nitrogen calculator

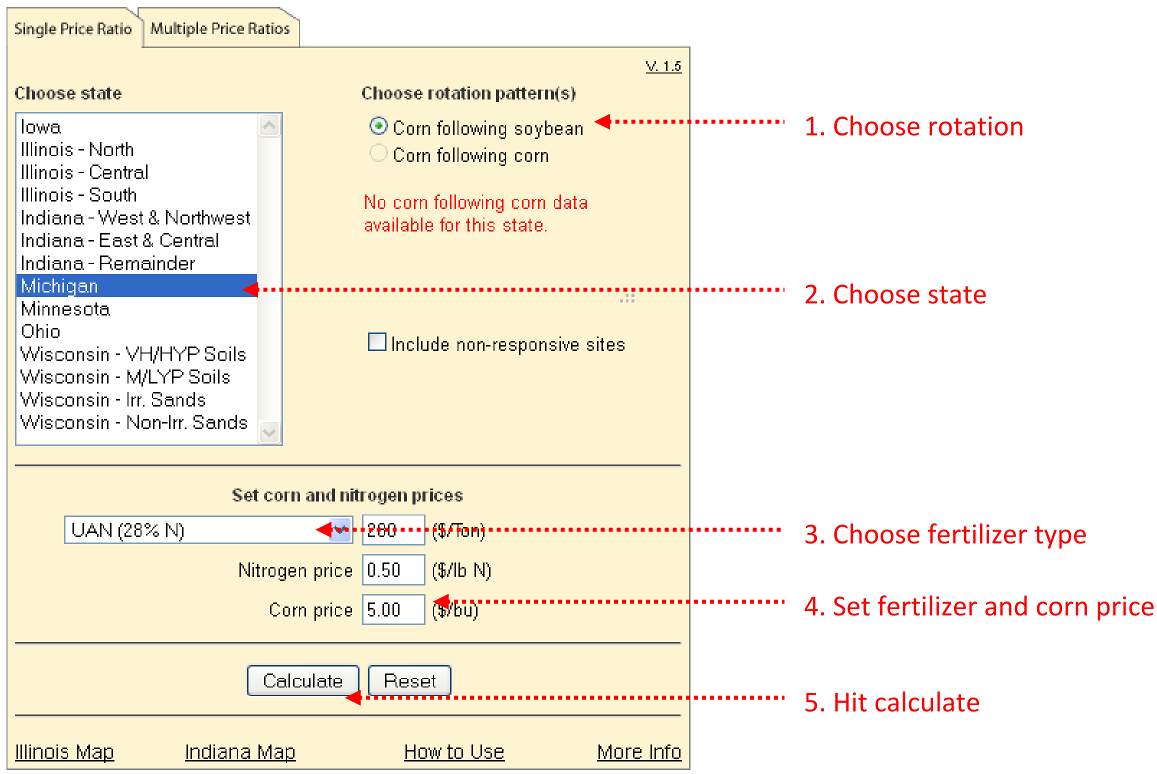

Figure H1. Screen shot of Iowa State University corn nitrogen calculator, showing selection menus for 1) rotation, 2) state, 3) N fertilizer type, and 4) N fertilizer and corn price.

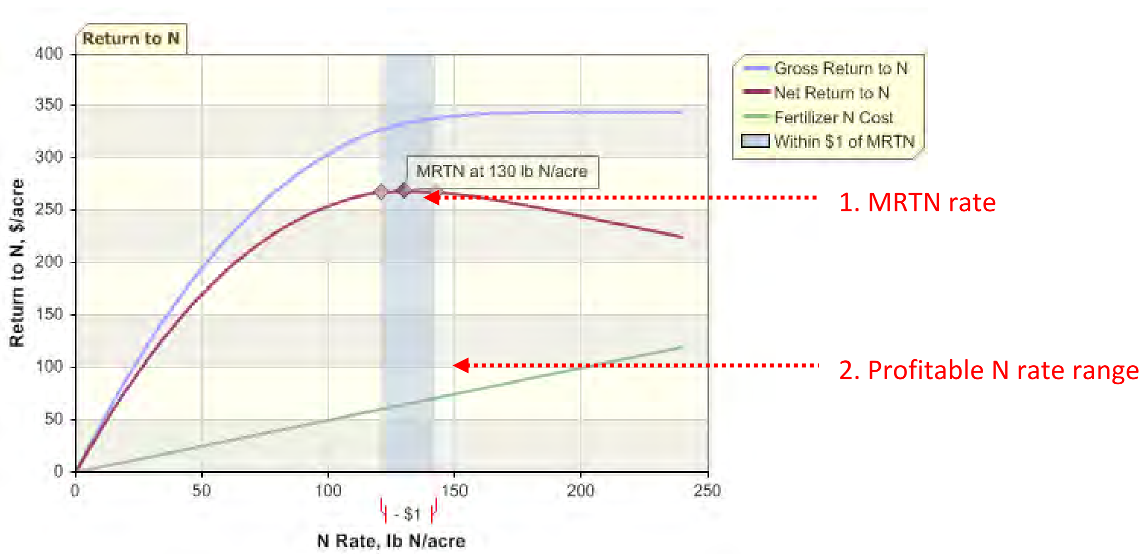

Figure H2. Screen shot of Iowa State University corn nitrogen calculator, showing 1) maximum return to nitrogen (MRTN) rate, and 2) profitable N rate range (blue shaded column; within $1.00 per acre of MRTN) for the project area specifications.

For the project conditions, the MRTN rate is 130 lb N acre^{-1}, with a profitable N rate range of 121 to 142 lb N acre^{-1}. For conversion from imperial units (lb N acre^{-1}) to metric (kg N ha^{-1}), the imperial value is multiplied by 1.12 (a conversion factor accepted by the American Society of Agronomy at http://www.soils.org/files/publications/journals-sitable-coversions.pdf). Therefore, in metric units the MRTN rate is 146 kg N ha^{-1}, with a profitable N rate range of 136 to 159 kg N ha^{-1}. 80% of the lowest recommended N rate is 109 kg N ha^{-1} (0.8 x 136 = 109); the proposed project N rate of 125 kg N ha^{-1} is higher than this so is consistent and eligible for use in the project area.

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