Methodology Synthesis to Supplement Nutrient Management Protocol Development

May 6, 2011

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1 Introduction

One important component of the Reserve's protocol development process is consideration of whether there are existing methodologies or protocols which could serve as a starting point, due to the fact that standardized protocols are more easily developed where sound scientific methods already exist to determine baselines and quantify emission reductions. A number of GHG offset protocols exist, in various stages of development, that address some combination of the activities the Reserve is considering for inclusion within the Nutrient Management Agricultural Project Protocol.

This "Methodology Synthesis" will supplement the Nutrient Management protocol development process by providing a review of three comprehensive and relevant protocols intended for use in voluntary and regulatory programs, including: (i) an existing protocol developed by Winrock International for the American Carbon Registry (ACR); (ii) a protocol developed by Michigan State University (MSU) and the Electric Power Research Institute (EPRI) that has been submitted to the Verified Carbon Standard (VCS) and the ACR for validation; and, (iii) a protocol approved for use in Alberta, Canada's Offset Program (Alberta). Implementation of projects under these protocols is limited, as each protocol has only recently been adopted or is still undergoing adoption, in each of their respective programs.

The purpose of the synthesis is to provide a quick reference for workgroup members and stakeholders to how key protocol criteria are addressed in other protocols and ultimately to inform discussion of similar elements in a Reserve protocol. Due to the primary focus of this Methodology Synthesis on the ACR, MSU-EPRI, and Alberta protocols, a brief overview of each of the respective programs is provided below. The remainder of the paper describes the protocol criteria and methodologies looking separately at each of the ACR, MSU-EPRI (in the context of VCS), and Alberta programs.

American Carbon Registry (ACR)

The American Carbon Registry (ACR) is a non-profit carbon market registry founded in 1996 originally as the GHG Registry and becoming part of Winrock International in 2007. ACR was the first private voluntary GHG registry in the U.S. ACR's protocol development process is led by a team of technical experts and includes both scientific peer review and public comment periods. Over the past 15 years, ACR has issued over 30 million project-based carbon offsets, called Emission Reduction Tons (ERTs). Quantification and verification protocols adopted under ACR must adhere to the *ISO 14064-2:2006* and *ISO 14064-3:2006* standards, respectively.

The *ACR Standard*[1] details programmatic requirements of ACR and includes "specifications for the quantification, monitoring, and reporting of project-based GHG emissions reductions and removals, verification, project registration, and issuance of offsets." Projects must fully adhere to the *ACR Standard*, as well as the relevant project protocol. "The ACR Methodology for N_2O Emission Reductions through Changes in Fertilizer Management" was adopted by ACR in November 2010.[2]

[1] American Carbon Registry (2010), *The American Carbon Registry (ACR) Standard,* Version 2.1, October 2011, Winrock International, Little Rock, Arkansas, Available at: http://www.americancarbonregistry.org/carbon-accounting/american-carbon-registry-standard-v2.0

[2] American Carbon Registry (2010), *American Carbon Registry Methodology for N2O Emission Reductions through Changes in Fertilizer Management.* Winrock International, Little Rock, Arkansas,

Michigan State University (MSU) and Electric Power Research Institute (EPRI) (MSU-EPRI)

The Electric Power Research Institute (EPRI) provided funding to Michigan State University (MSU) to conduct a three-year field study evaluating different approaches to quantify and reduce N_2O emissions from nitrogen-based fertilizer in commercial field crop production, the results of which became the basis for the MSU-EPRI methodology entitled "Quantifying N2O Emissions Reductions in US Agricultural Crops through N Fertilizer Rate Reduction."[3] The MSU-EPRI methodology was submitted to the Verified Carbon Standard (VCS) and posted to their website for public comment in September 2010. Its first validation under the VCS Double Approval Process was completed successfully in spring 2011, and the methodology currently is undergoing the 2nd required VCS validation. The MSU-EPRI methodology also has been submitted for validation to the ACR and is now undergoing formal ACR review. The analysis presented in this paper is based on methodology version 1.4, as submitted to VCS in February 2011.

Development of the VCS (previously called the Voluntary Carbon Standard) began in late 2005, led by The Climate Group, the International Emissions Trading Association and the World Economic Forum. The first program standard (*VCS Version 1*) was released in March 2006 and has since undergone further revisions, public comment periods, etc. A 19-member Steering Committee was established to consider stakeholder comments, and numerous technical working groups have been convened to advise on a host of issues. The World Business Council for Sustainable Development partnered with VCS in 2007. Quantification and verification protocols adopted under VCS must adhere to the *ISO 14064-2:2006* and *ISO 14064-3:2006* standards, respectively.

The VCS has a number of programmatic documents relevant to consideration of this methodology. The *VCS Standard, version 3*,[4] which was released in March 2011, is important to understanding general program policies. However, as fertilizer application falls under land-use management, the *AFOLU Requirements, Version 3.0* document is also applicable. A document summarizing "Program Definitions" is provided on their website, as well as a "Program Guide," which provides a broader overview of its founding, its goals, and its history.

Alberta Offset System

The Canadian province of Alberta is one of "the first jurisdictions in North America to impose comprehensive regulations requiring large facilities in various sectors to reduce their greenhouse gas emissions." Under the provincial "Climate Change and Emissions Management Act," Alberta has required annual reporting of air emissions since 2003, and the Specified Gas Emitters Regulation, which went into effect July 1, 2007, established a regulatory framework for the Alberta Offset System through emission reduction targets for regulated entities and guidelines for achieving compliance. Additional information on the Alberta legislation, regulation,

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Available at: http://www.americancarbonregistry.org/carbon-accounting/emissions-reductions-through-changes-in-fertilizer-management

[3] Michigan State University and Electric Power Research Institute (2010), "MSU-EPRI Methodology Proposal: Quantifying N2O Emissions Reductions in US Agricultural Crops through N Fertilizer Rate Reduction, July 2010, Verified Carbon Standard, Available at: http://www.v-c-s.org/docs/VCS%20N2O%20Reduction%20Methodology%20and%20Annexes%20v1.pdf

[4] Verified Carbon Standard (2011), *VCS Standard, version 3.0, Requirements Document,* March 2011, Available at: http://www.v-c-s.org/docs/VCS%20Standard%20-%20v3.0.pdf

and policy development is available on their website, as is more specific information on their Offset System. Alberta also provides a "Technical Guidance for Offset Project Developers"[5] document and an "Alberta Offset Credit Verification Guidance Document."

The Alberta system has approved numerous protocols, the full list of which is available on its website, with many more currently under review and in various stages of development. The "Quantification Protocol for Agricultural Nitrous Oxide Emissions Reductions" adopted for use in Alberta in September 2010 is particularly relevant to the Reserve's Nutrient Management protocol development and will be reviewed here.[6] Additional technical background documents, used during protocol development, are also available.

2 Project Eligibility and Other Requirements

ACR

Project Definition and Eligibility Criteria

- The project is defined as "Agricultural Land Management (ALM) ACR project activities that involve a change in fertilizer management," which may include "changes in fertilizer rate (quantity), type, placement, timing, use of timed-release fertilizers, use of nitrification inhibitors and other factors."
- Management practices must involve the "use of fertilizer for enhancing crop growth and survival on agricultural lands" in both the baseline and project scenarios.
- Project activities may not lead to a significant decrease in yields. (If yields are significantly affected, the project is ineligible.)
- There may be no increase in fertilizer use outside of the project boundary, on any/all crops on land owned or managed by the owner/manager of the project site.
- Organic soils (histosols) are eligible under this methodology. It should be noted, however, the biogeochemical process model used to quantify emissions under the ACR protocol (DNDC) by simulating "DeNitrification-DeComposition" of nitrogen and carbon in agro-ecosystems may not be applied for histosols. Though these organic soils would otherwise be eligible, the methodology does not state how to quantify the emissions from this soil type.
- The project may "not involve the drainage or flooding of wetlands."
- Farms must have "records of yields and fertilizer application amounts from at least 5 previous years."
- Projects are required to incorporate a minimum of 10 individual fields. Fields may be adjacent to each other, but must be "justifiable" as distinct fields during verification. The fields in a project may or may not be owned by the same landowner, as long as the combined areas are treated as a single project area. The methodology does not otherwise specify a minimum project size (e.g. in acres).

Geographic Eligibility

- The protocol does not restrict geographic eligibility.

[5] Alberta Environment (2011), "Technical Guidance for Offset Project Developers," Version 2.0, January 2011, Available at: http://environment.gov.ab.ca/info/library/7915.pdf
[6] Alberta Environment (2010), "Quantification Protocol for Agricultural Nitrous Oxide Emissions Reductions," Version 1.0, October 2010, Available at: http://environment.gov.ab.ca/info/library/8294.pdf

- The protocol is inferred to have wide geographic applicability because the ACR program overall (per the *ACR Standard)*, accepts projects from within and outside the US.
- Though the DNDC model is theoretically applicable to a wide geography as well, it should be noted that the model requires significant input data for calibration and validation. As such, there may be geographic locations for which sufficient data will not be available to calibrate the model.

Ownership

- Ownership requirements are not described explicitly in the protocol. However, it is implied that the project developer may be either a landowner or an entity with authority to make fertilizer management decisions (e.g. a lessee) over the project lifetime. The project developer must also describe "legal title to the land, rights of access to the avoided GHG emissions, current land tenure, and fertilizer management for each discrete area of land."
- The *ACR Standard* adds that the project participant shall provide "land ownership documentation and attestation of clear, unique, and uncontested land title." Further, "land title may be held by a person or entity other than the Project Proponent, provided the Project Proponent has clear, unique, and uncontested offsets title."

Start Date

- As noted within the protocol, the *ACR Standard* defines the Start Date for agriculture, forestry, and other land use (AFOLU) projects as "the date on which the Project Proponent began the activity on project lands."
- Both the *ACR Standard* and protocol state that projects with a Start Date on or after November 1, 1997 are eligible.
- According to the protocol, if the Start Date claimed by the project proponent is prior to submission of a GHG Project Plan, additional evidence demonstrating the project start *and* demonstrating that the carbon incentive was considered in "the decision to proceed with the project activity" is required.
- The protocol notes that AFOLU projects with a Start Date prior to November 1, 1997, may be accepted by ACR on a case-by-case basis, provided the Project Proponent can demonstrate with appropriate documentation that GHG mitigation was an objective from project inception."

Crediting Period

- The ACR methodology states that "change in fertilizer management project activities may be implemented for one year or longer." The duration of the crediting period is not more explicitly clarified in the protocol, with the protocol referring to the *ACR Standard* or "relevant ACR sector standard" for further details on the crediting period. Though the *ACR Standard* does not specify a typical AFOLU crediting period length and no AFOLU sector standard exists other than the forest project standard, one can infer that the "non-AFOLU" circumstances of a 7-year crediting period apply.
- Communications with ACR clarify the crediting period policy further, indicating that the crediting period is actually variable, as chosen by the project developer. The crediting period may be as short as 1 year or as long as 7 years.
- Regardless of the length of crediting period chosen, the baseline initially justified at the start of the project is used throughout the duration of the project.

Additionality

- The project must pass the three-pronged ACR additionality test, as described in the *ACR Standard*.
- A project passes ACR's "Regulatory Surplus" test if there is no "existing law, regulation, statute, legal ruling, or other regulatory framework in effect…that mandates the project activity or effectively requires the GHG emissions reductions."
- The second prong is referred to as the "common practice test", which requires the project developer to demonstrate that the project activity is not "common practice" in the region where the project is located (i.e. there is not "widespread deployment of this project, technology, or practice within the relevant geographic area").
- An "Implementation Barriers" test, is the third prong, which requires project developers to demonstrate that there exist significant barriers to implementing the project (e.g. financial, technological, or institutional constraints), which could only be overcome with carbon market incentives.
- Finally, the project developer must identify all "plausible alternative fertilizer management scenarios" which may have occurred in the absence of the project. Plausibility is determined by applying the three tests above to each baseline scenario. All alternative scenarios must be considered and a list of plausible alternative scenarios provided. The project activity is not considered additional if it could be included in the list of plausible alternative scenarios, in the absence of the carbon incentive.

Aggregation

- The methodology requires combining at least 10 individual fields, which may be owned by the same landowner or distinct landowners.
- "Aggregation of agricultural properties with multiple landowners is permitted under the methodology, with aggregated areas treated as a single project area"

MSU-EPRI

Project Definition and Eligibility Criteria

- The project is defined as: activities that "reduce net nitrous oxide (N_2O) emissions from agricultural cropping systems by reducing nitrogen (N) fertilizer rate."
- Eligible project sites are those on which "eligible cropping systems have been grown for at least ten years prior to project implementation."[7] Eligible cropping systems are those that have received eligible sources of fertilizer nitrogen (N), including synthetic N fertilizers and organic N fertilizers.
- Irrespective of source, all eligible N inputs are considered equal and calculated on a mass basis.
- Best Management Practices (BMPs) for the management of synthetic and organic N fertilizer must be followed at the project site for the duration of the crediting period. The protocol does not require adherence to a particular set of BMPs, instead referring to those specified by state departments of agriculture and federal agencies such as the Natural Resources Conservation Service (NRCS) and the USDA Farm Service Agency. BMPs generally include recommendations for N rate determinations, timing, placement, and formulation, as also described by the "Global 4R Nutrient (Fertilizer) Stewardship

[7] Under the version of the MSU-EPRI protocol submitted to the ACR, this eligibility requirement is a shorter 5 year period consistent with ACR's guidance and requirements.

Framework (Right Source-Rate-Time-Place)," published by the International Plant Nutrition Institute (IPNI).

- Projects located on croplands with organic soils, also known as histosols (as defined by the US Soil Taxonomy, USDA, and NRCS) are ineligible.
- The project and baseline crop area must be located on the same cropland, with the project area equal or less than the baseline crop area.

Geographic Eligibility

- Projects within the United States are eligible.[8]
- While all regions of the US are eligible, two different quantification methodologies are included for calculating direct N_2O emissions based on geography and crop type.
- "Method 1" is applicable to all eligible locations and crops, while "Method 2" is applicable for all corn rotations (e.g., continuous corn, as well as corn rotations with other crops such as soybeans or wheat) within the 12-state North Central Region (NCR) of the US (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin).

Ownership

- No discussion of ownership is included in the methodology itself, as this issue is addressed separately in the applicable VCS standard.
- The *VCS Standard* requires submission of proof of title to demonstrate right of use to the cropland and subsequently, unambiguous ownership of the GHG emissions reductions for each project.

Start Date

- The protocol does not explicitly provide a start date policy, as this is addressed in the VCS AFOLU Requirements and other VCS standard documentation.
- According to the *VCS AFOLU Requirements* document, the project start date is "the date on which activities that lead to the generation of GHG emission reductions or removals are implemented. Such activities may include preparing land for seeding, planting, changing agricultural or forestry practices, or implementing management or protection plans."
- According to the *VCS Standard*, projects must generally have a start date on or after January 1, 2002.
- However, projects with start dates prior to January 1, 2002, which can demonstrate both that an alternate, externally reviewed methodology was applied and that "the project was designed and implemented as a GHG project from its inception," may be able to register, assuming the project was validated and verified by October 1, 2011.

Crediting Period

- The protocol refers to the rules for ALM projects "focusing exclusively on emissions reductions of N_2O as set out in the most recent version of the VCS Standard."
- Currently, the most recent VCS Standard (version 3) states that for agricultural projects reducing N_2O emissions, the crediting period is 10 years and is renewable two times (at most).

[8] Under the version of the MSU-EPRI protocol submitted to the ACR, international projects are eligible.

Additionality

- The protocol requires projects to exceed their business-as-usual N rate, which is assessed one of two ways. When historical, verifiable farmer records are available, a project-specific baseline is established. When records are not available, the methodology uses a standardized approach to derive a baseline using county-level yield data and state-recommended fertilizer rates to achieve average yields. Project reductions are calculated as a direct function of fertilizer application rates below the baseline. More details on how baseline and project emission are calculated are provided in Section 4.
- The protocol states that there must be 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 or common–practice scenario."
- The methodology notes that no "Federal fertilizer statute" exists and that "fertilizers are regulated under the individual States' authority." However, the methodology also notes that the Federal government does regulate hazardous waste, water and air quality, all of which may be indirectly related to the use and application of fertilizers.
- The Safe Fertilizer Information Institute is referred to as a good resource for obtaining further information on existing regulatory requirements. Annex D of the methodology provides additional information on potentially relevant legal requirements.
- The protocol also summarizes a number of the barriers preventing producers from implementing N-rate reductions, including that economic optimization of N-rate is counter to historical recommendations, the lack of financial incentive for producers to make the change, and the high comfort level producers have with their traditional N-rates.

Aggregation

- The protocol does not explicitly address aggregation or project grouping,
- The VCS allows a form of aggregation called "project grouping," under which multiple activities may be brought together under a single project with a common monitoring and information system.

Alberta

Project Definition and Eligibility Criteria

- A project is defined as "switching to an integrated set of Beneficial Nitrogen (N) Management Practices (BMPs) for annual and perennial cropping. These BMPs manage applied nitrogen sources in a more comprehensive and sophisticated way to reduce nitrous oxide emissions associated with nitrogen fertilizer application [through implementation of]…a new technology called a Consistent 4R (Right Source @ the Right Rate, the Right Time and the Right Place) Nitrogen Stewardship Plan."
- Offset credits are generated when "the entire, comprehensive 4R Consistent Nitrogen Stewardship Plan [is implemented] at the appropriate performance levels as dictated by this protocol...Projects that implement only individual elements of the new technology are not eligible."
- Farm-specific 4R Consistent Nitrogen Stewardship Plans (4R Consistent Plan) must be developed by an Accredited Professional Advisor (APA), according to a certain BMP performance management level (Basic, Intermediate, Advanced).

- The Accredited Professional Advisor identifies the baseline practices as part of the 4R Consistent Plan development. If a basic level of BMP performance is found by the APA, implementation of intermediate or advanced performance level is required for the project condition. The rationale for including projects that are already using a basic level of BMP implementation is that these farmers would not be achieving the level of N_2O emission reductions possible at the more advanced level and that the more advanced levels provide more assurance that N_2O reductions are achieved.
- "All eligible land managed by the participating farm [must be] included in the 4R Consistent Plan and in the quantification of emissions and reductions." This implies that, if a farm chooses to participate in a project, project activities must be implemented on all eligible land—the project cannot pick and choose which fields will be enrolled.
- Both annual and perennial crops are eligible, including forages grown for silage or bailed.
- Both synthetic and organic fertilizers are eligible. Organic fertilizers include manure, pulse crops, and presumably compost, though compost is not explicitly noted.
- Grazing lands, including "swath grazing" and "cattle on stubble," are ineligible.
- A project may be implemented simultaneous to a Tillage System Management project, as the protocols are meant to be "'stacked' to create greater opportunities for farms."
- Eligible management activities may be expanded and included in the project at a later date on newly acquired land holdings, newly leased lands, and new crops not previously included, as long as "three years of baseline data on crop events prior to including the crop" or land area in the farm/project can be established.

Geographic Eligibility

- Under Alberta's Offset Program, only offset projects implemented within the province of Alberta are eligible.
- Specific requirements for each of the three BMP Performance Levels (Basic, Intermediate, Advanced) of the 4R Consistent Plan vary by region. Eligible regions are divided by "drier" and "moister" soils, based on a Precipitation/Potential Evapotranspiration ratio (P/PE) threshold of 1.0 (drier soils have $P/PE < 1$; wetter soils have $P/PE >= 1$).

Ownership

- Before undertaking a project, "legal ownership of the GHG reductions and removals must be established by contract or other legal agreement."
- A project may be "implemented by the land lessee and not the land owner," assuming such a contract exists.
- Similarly, a project may be implemented on "crown land" (i.e. analogous to federally owned land in the US), assuming the proper GHG ownership contracts are in place.

Start Date

- Generally, the project start date for all Alberta protocols is "the first day of operation of the facility or project," which must occur on or after January 1, 2002.
- For this protocol, the project "is initiated by implementation of the 4R Consistent Plan."
- At least 3 years of historic data on crop management and yield are required, prior to the start date, to set the project-specific baseline.

Crediting Period

- The project crediting period is 8 years, with the possibility of a 5 year extension.
- Additional crediting periods will likely necessitate reassessment of the baseline.

Additionality

- Under Alberta's Offset Program, emission reductions resulting from actions required by law are not eligible. However, the protocol does not provide a further review of legal requirements that may affect the project type.
- According to the protocol, analysis of "independent survey data of nutrient management practices across the country show that it is highly unlikely the complete suite of practices associated with the 4R Consistent Plan, applied consistently every year, is a common practice." Therefore, projects that adopt the 4 R Consistent Plan are considered additional.
- A 2001 survey from StatsCanada reveals that "only 11% of Alberta's farms develop and implement nutrient management plans," while a 2006 survey from IPSOS "indicate[s] a majority of plans were prepared by growers without support of trained advisors."
- The protocol further asserts that "field-scale BMPs (Basic level) have informational and financial barriers," while "landscape-directed BMPs (Intermediate and Advanced levels) have technological and financial barriers."

Aggregation

- While it is clear that some sort of aggregation is allowed for within the protocol, extensive details on how aggregation would work for this project type are not provided. While aggregation is an important protocol development issue, details on the Alberta aggregation approach are not further elaborated in this paper and will be a topic for future discussion.

3 Project and GHG Assessment Boundaries

ACR

GHG Assessment Boundaries

Both direct and indirect N_2O emissions resulting from fertilizer application are included.

The methodology also accounts for changes in emissions resulting from fossil fuel combustion (CO_2, CH_4, N_2O) and GHG emissions from offsite fertilizer production.

Any changes to soil carbon stocks resulting from fertilizer management are assumed to be positive, making the exclusion of soil carbon pools conservative (or *de minimis).*

Project Boundaries

The physical project boundary includes the discrete area of land under the control of project participants on which the ALM project activity is implemented. The project boundary may include more than one discrete area of land.

Leakage

Leakage is addressed through eligibility criteria, which dictate that "projects must not lead to a significant decrease in yields." As such, leakage is assumed to equal to zero. A subsequent section of the protocol requires project developers to "demonstrate" this by comparing DNDC yield estimates of the baseline and project scenarios, showing that total yields shall not be decreased by more than 5% in any given year.

Additionally, the methodology requires project developers to demonstrate that there has been no increase in fertilizer use on other fields under their management outside the project boundary.

Finally, the protocol recognizes that there may be "positive leakage" (e.g. yield increases due to the project). However, the protocol does not quantify nor credit positive leakage, saying that this will further increase the net environmental benefit of the project and improve conservativeness.

MSU-EPRI

GHG Assessment Boundaries

The methodology states that "N_2O is the major emissions source from fertilizer N addition," and as such, is the only GHG included in the Assessment Boundary.[9] Direct and indirect N_2O emissions are included in both the baseline and project Assessment Boundaries.

Though soil carbon is "the primary pool of concern for ALM (Agricultural Land Management) Methodologies,…reductions in fertilizer N rate resulting from project implementation will not result in significant…decreases in soil C stock," and as such, this reservoir is excluded from the GHG Assessment Boundary. Annex B of the methodology provides further rationale as to why excluding the soil carbon reservoir is conservative.

Emissions from the combustion of fossil fuels are not included. Though the protocol does not appear to consider this source, protocol developers confirm that fossil fuels were considered and were estimated to be identical under both the baseline and project scenarios, thereby not affecting net changes in GHG emissions from an N2O reduction project.

Project Boundaries

For direct N_2O emissions, the project boundary is the "physical crop site(s) where fertilizer N is applied." For indirect N_2O emissions, however, the project boundary is the "physical site(s) *beyond the crop site* where fertilizer N deposition occurs." (Emphasis added)

Leakage

Leakage risks are considered "negligible," as projects will be at sites on which "eligible cropping systems have been grown for at least ten years prior to project implementation." Additionally, in accordance with VCS AFOLU Requirements, the protocol notes that leakage "attributable to market effects is not applicable with this AFOLU ALM project methodology."

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[9] See Millar, N, G.P. Robertson, P. R. Grace, R.J. Gehl, & J.P. Hoben. 2010. "Nitrogen fertilizer management for nitrous oxide (N_2O) mitigation in intensive corn (Maize) production: an emissions reduction protocol for US Midwest agriculture." Mitigation and Adaptation Strategies for Global Change 15:185–204.

The protocol assumes that reduced N rates “will not result in average crop yield reductions” and that therefore “there will be no associated requirement for increased production outside of the project boundary, which might then result in increased N fertilizer use and N2O emissions.” That said, there is no eligibility criterion in the protocol that restricts projects from allowing for yield decreases.

Finally, the protocol notes that “positive leakage” is not eligible, but that regardless, “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^-).”

Alberta

GHG Assessment Boundaries

The GHG assessment boundary considered by the Alberta Protocol is relatively broad, with the protocol identifying a host of upstream and downstream “related” sources and sinks, such as seed production and fuel delivery, many of which are ultimately excluded from project quantification. The rationale for the exclusion of those sources/sinks from quantification is that they are likely to be equivalent in the baseline and project conditions. However, the protocol states that “project developers must assess these emission sources for their specific project,” and if the assumption that emission sources are equivalent proves to not be valid for a given project, “the associated emissions must be quantified and documented.” Emissions from upstream fertilizer and lime production (SS 5) are also considered but ultimately excluded because emissions from fertilizer production will either not change or decrease as a result of the project; therefore excluding SS5 is considered conservative.

Of the 22 related or controlled sources and sinks identified for baseline and project conditions, 3 pairs (e.g. baseline and project source counted as one “pair”) of on-site sources/sinks are included in Alberta’s quantification methodology. These sources/sinks include:

- Fertilizer and lime distribution (SS 7)
- Fertilizer and lime use (SS 8)
- Soil crop dynamics (SS 13)

SS 7 (“On-Site Fertilizer and Lime Distribution”) captures the fuel use associated with “the management of fertilizer, manure and crop residues for each annual or perennial crop type grown.” An increase in fuel use associated with fertilizer and lime distribution might come from a project activity such as split fertilizer application. However, in an effort to provide more flexibility in implementing the protocol, SS 7 may be excluded from quantification if the project developer can “demonstrate that no increased fuel use has occurred as a result of implementing the 4R Consistent Plan.”

The remaining sources, SS 8 (“Fertilizer and Lime Use”) and SS 13 (“Soil crop dynamics”), are the primary sources controlled by implementation of the project activity. SS 8 is meant to track “timing, composition, concentration, and volume of fertilizer,” while SS 13 captures “flows of materials and energy that comprise the cycling of soil and plant carbon and nitrogen, including deposition in plant tissue, decomposition of crop residues, stabilization in organic matter and emission as carbon dioxide and nitrous oxide.” Because of the complex emissions pathways and interactions between the two sources, the quantification methodology ultimately requires much of the quantification of SS 8 and SS 13 together. It is also important to note that though “soil dynamics” are included, the protocol explicitly states that emission reductions associated with carbon sequestration in the soil are excluded.

The Alberta protocol specifically addresses “modularity” in agriculture protocol development. Explicitly recognizing the interdependent nature of agricultural management practices, this fertilizer management protocol “applies to a single component (nitrogen management) of farm operations.” The protocol was developed in such a way that it could be “layered” or “stacked” with other protocols ”where multiple projects are undertaken to lower overall greenhouse gas emissions from farm operations.” Though not explicitly noted in this protocol, Alberta’s Tillage Management Protocol, in particular, notes that it was meant to be “stacked” with the Nitrogen Management protocol.

Project Boundaries

The project refers to the aggregate of participating farms. The project boundary on each farm is *all* eligible farmland managed by that particular farm.

Leakage

The Alberta protocol quantifies offsets as a function of a change in GHG emissions intensity (N_2O/kg crop produced) from the baseline to the project. Relative to an absolute emission reduction calculation, this approach will reduce the offset quantity when yields decline under the project and increase the offset quantity when yields increases under the project relative to baseline yields on an equivalent area of land.

This approach directly accounts for potential leakage impacts as a result of yield reductions at the project site. Reductions in yield at a project site may result in yield increases outside the project boundary, leading to corresponding GHG emissions increases associated with the yield increases outside the project boundary.

Extreme project yield decreases, however, can actually result in the quantification of net emissions increases under this approach even if absolute emissions did not change or decreased. The protocol states that in cases where “catastrophic crop failure” (and associated yield decreases) occur as a result of drought, frost, hail, wheat infestations, etc., the “affected land area” may forgo reporting for that year. If catastrophic crop failures occur, the Accredited Professional Advisor must discuss the affected land area in his/her post-harvest assessment.

On the other hand, this approach allows for a situation in which it is possible for a project to receive GHG reduction credits, even when absolute GHG emissions at the project site increased. This could occur when yield per unit area increases by proportionally more than N_2O emissions per unit area, relative to the baseline. Offset credits would essentially be awarded for positive leakage, based on the presumption that growing more crops with less N input will decrease demand and yields outside the project boundary, thereby resulting in an economy wide decrease in N_2O emissions. In this case, the Alberta methodology credits indirect emission reductions.

4 Quantification Methodology

A brief synopsis on the quantification methodology of each protocol is provided here for reference. In depth analysis and comparison of quantification methodologies is beyond the scope of this paper, but will be undertaken as part of the Reserve's protocol development process.

ACR

All projects must use the most current version of the DNDC model to calculate direct and indirect emissions from fertilizer application in the baseline and the project. Direct N_2O emissions estimates result from DNDC simulations of soil carbon and nitrogen biogeochemistry. DNDC also models nitrogen leaching and volatilization loss rates, which are combined with the IPCC Tier 1 emissions factor to determine indirect N_2O emissions. Emission factors are used to quantify baseline and project emissions from fossil fuel combustion and offsite fertilizer production, which are provided in the protocol's parameter table. Default emission factors for both fossil fuels and fertilizer production are derived from the 2006 IPCC National Greenhouse Gas Inventory Guidelines.

When projects are implemented on a non-homogenous project area, the project area must be stratified (into distinct "strata") on the basis of key parameters, such as management regime, soil type, planting history, etc. The DNDC model must be run separately for each stratum for the purpose of improving model accuracy.

Extensive guidelines are provided on how to calibrate the DNDC model for the specific site conditions of the project, as well as how to adjust the model to ensure that uncertainty is accurately accounted for (e.g. uncertainty greater than 10% requires an uncertainty deduction). To run DNDC, inputs on the location and type of crops grown, local climate, soils and agricultural management practices are required. According to the protocol, inputs must be based on project-specific circumstances and, depending on the variables, may be based on site measurements, project records, default values, or values in the scientific literature. The proper choice of parameters is necessary for DNDC to accurately simulate N_2O emissions. Therefore, DNDC must be calibrated for all crops included in the project area.

The DNDC calibration process involves iterating on a set of plausible parameters as inputs until modeled yield values closely match actual yield data. Model results must be compared to a minimum of 5 years of observed yields. To do so, once all initial parameters have been entered into the model, the model should be run and the mean absolute deviation (MAD) evaluated, as compared to observed yields. If MAD is less than 10%, crop calibration is complete. If MAD is greater than 10%, input parameters must be further refined and adjusted until MAD decreases below 10%. Selection of parameters must be both justified and conservative, i.e. "if different values for a parameter are equally plausible, a value that does not lead to under-estimation of net GHG emissions must be selected."

The uncertainty ranges for input parameters must also be defined in order to run a Monte Carlo simulation, which enables derivation of confidence intervals around model simulations. Soil parameters may be estimated one of two ways:

- If field measurements are used, "the target precision level for each soil parameter shall be +/- 10% of the mean at a 90% confidence interval," and it should be assumed that field values are normally distributed."

- If soil surveys from NRCS SSURGO are used, then default uncertainty estimates and probability distribution functions, listed in the protocol's Table 3, must be applied.

Once the DNDC model is calibrated, a Monte Carlo run must be performed for each distinct stratum. As "previous cropping history has an impact on N_2O emissions" and must be accounted for, DNDC model simulations are run over a two year period to model baseline emissions, including both the baseline year and the year preceding it. For project emissions, DNDC model simulations are run for the duration of the project ("e.g. two year projects should perform a two-year Monte Carlo run"). The resulting emissions estimates for each stratum must be averaged and later multiplied by the area of the respective stratum. In simple terms, a stratum-specific emission factor is created and applied to the respective land area.

As a final quantification step, the total model uncertainty (at the 90% confidence level for individual model runs) is calculated to determine the magnitude of "uncertainty deduction" that must be applied to the emission reduction estimates, if any. If total uncertainty is less than or equal to 10%, no uncertainty deduction is required. However, if uncertainty is greater than 10%, the deduction should be the difference between total uncertainty and 10%, multiplied by the total emissions reductions calculated. (e.g. if uncertainty is 18%, then the deduction should be equal to [8% x Emission Reductions]). As the choice of input parameters affects the uncertainty evaluation, the project may choose to incorporate more site-specific measurements as model inputs to help reduce model uncertainty.

MSU-EPRI

The protocol uses the fundamental emission factor methodology developed by the Intergovernmental Panel on Climate Change (IPCC) to estimate direct and indirect N_2O emissions for both the baseline and project. Depending on the region where the project is located, one of two methodologies is applied, representing the IPCC Tier 1 and Tier 2 methodologies respectively.[10] The Tier 1 methodology ("Method 1" in the protocol) may be applied to all eligible cropland, while the IPCC Tier 2 approach ("Method 2") applies to corn rotations in the North Central Region (NCR) of the US.[11]

In general, the IPCC Tier 1 and Tier 2 methodologies estimate direct N_2O emissions by multiplying the amount of nitrogen applied to crops by an emission factor expressed as N_2O per unit of N applied. Indirect emissions are also a function of the amount of nitrogen applied, multiplied by a factor that separates out how much of that nitrogen goes into each of the indirect sources (volatilization/deposition and leaching/run-off). The adjusted mass of nitrogen is then multiplied by emission factors for volatilization/deposition and leaching/run-off. [Direct emissions calculations also take into account the fraction of nitrogen lost to volatilization/deposition and leaching/run-off]

According to the MSU-EPRI protocol, for all regions except NCR, Method 1 applies the IPCC Tier 1 default factors to estimate both direct and indirect emissions (Mg CO2e/ha/yr), using the respective N input data. For corn systems in NCR (Method 2), a Tier 2 emission factor is used

[10]The distinction between IPCC's Tier 1 and Tier 2 quantification methodologies is that Tier 1 applies a default emission factor to actual land-use data, while the Tier 2 methodology applies a more specific, regionally-derived emission factor. For a more complete discussion of the IPCC Tier 1 and 2 methodologies, see the "Introduction" (Chapter 1) to the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, available at: http://www.ipcc-nggip.iges.or.jp/

[11] The NCR includes Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin.

to estimate direct emissions, as well as the same IPCC Tier 1 defaults to estimate indirect emissions. In both Methods 1 and 2, the project emissions are subtracted from baseline emissions (both are in units of Mg CO2e/ha/yr) and then multiplied by the project area.

The Method 1 default of 0.01 Mg N_2O-N/Mg N input assumes a linear, directly proportional rate of increase in N_2O with an increase in N input. The Method 2 emission factor was derived from multi-year field studies conducted in Michigan at sites broadly representative of Midwestern crop rotations and conditions (e.g. soil type, texture, and grain yield). Results from these studies have been corroborated at additional sites, with results recently published in the peer-reviewed literature.[12] The Method 2 emission factor is non-linear and reflects research showing that N_2O emissions increases exponentially with increasing fertilizer application rates, and in particular at rates greater than crop N uptake.

Baseline nitrogen application rates are determined from historical data in one of two ways:

- In Approach 1, the baseline is an average N application rate (Mg N/ha/yr) derived from the project proponent's management records for the previous five years for continuous corn or six years for a 2- or 3-crop rotation (e.g., for corn-soybean or corn-soybean-wheat rotations).
- Approach 2 is used when farmer records are not available to support the use of Approach 1. In Approach 2, baseline N application rates (Mg N/ha/yr) are derived from county-level crop yield data and equations that provide state fertilizer application recommendations based on yield goal estimates. Note: Approaches 1 and 2 for historical N use should not be confused with Methods 1 and 2 for estimating N_2O emissions)

Project fertilizer application rates (Mg N/ha/yr) are based on actual amounts applied during the project. Yearly fertilizer N rate is determined based on total fertilizer N additions to the soil during a complete crop cycle, irrespective of calendar year.

The protocol explains the primary sources of uncertainty in the calculations, noting that use of Method 2 will minimize uncertainty relative to Method 1 and Approach 2 will increase uncertainty relative to Approach 1. However, Approach 2 will also provide a conservative estimate of baseline nitrogen use. Variation in on-farm nitrogen management during the project will be minimized because of the requirement to adhere to a BMP at the project site. Explicit calculation of and/or adjustments for uncertainty are not required.

Alberta

The Alberta quantification methodology uses eco-region emission factors that represent baseline N_2O emissions and are derived from Canada's National GHG Inventory. The eco-region emission factors are used to derive baseline and project emission intensity values (N_2O emissions per unit of crop produced), as follows:

Direct N_2O emissions are estimated for each source of nitrogen input (i.e., fertilizer, manure, crop residue) and for each field producing a specific crop by multiplying the volume of nitrogen applied by a corresponding eco-region specific emission factor (kg N_2O-N per kg N).

[12] J.P. Hoben, R. J. Gehl, N. Millar, P.R. Grace, and G.P. Robertson, "Nonlinear nitrous oxide (N2O) response to nitrogen fertilizer in on-farm corn crops of the US Midwest," Global Change Biology (2010), 17:1140–1152.

Indirect N_2O emissions from volatilization and redeposition of NH_3 and NOx are also estimated for each nitrogen source, using eco-region default values for the fraction of nitrogen that ends up volatilized or re-deposited and a corresponding emission factor (kg N_2O-N per kg N). Indirect N_2O emissions from leaching are also similarly estimated with fractions and emission factors.

All direct and indirect emissions estimates for a given crop are combined and summed across nitrogen sources and fields for a crop-specific total N_2O emissions estimate. The N_2O emissions are divided by total yield of that crop to give emission intensities in units of N_2O per kg of crop produced, and units are converted to CO_2 equivalents.

Three years of historical data on nitrogen inputs and crop yields are used to develop the baseline emission intensity value.

To develop project emissions intensity values, data on nitrogen inputs and crop yields over the project reporting period are used. In addition, an "emissions reduction modifier" is applied to the project emissions intensity value according to the level of BMPs applied (0.85 for Basic and 0.75 for the Intermediate and Advanced levels). The modifier has the effect of reducing project emissions intensity according to the level of BMP applications.

The difference between baseline and project emission intensities is calculated and then multiplied by the crop yield during the project crediting period to estimate emission reductions or offsets. This is done separately for each type of crop in each separate eco-region and then summed for an estimate of total offsets.

Note that according to the protocol, the crop areas used to derive the baseline emission intensity values do not need to correspond exactly to crop areas covered by the project emissions estimate.

If the project activity increased the number of fertilizer applications (e.g. employed split application), fuel use associated with fertilizer and lime distribution is likely to increase, in which case these emissions must be quantified, and subtracted out of the total emission reductions. The methodology for quantifying those fuel use emissions is straightforward, as would be expected, with volume of fuel used multiplied by the respective emission factors for CO_2, CH_4, N_2O, and all emissions summed.

5 Verification and Reporting

ACR

The protocol largely refers to the *ACR Standard* to clarify verification requirements. A verification field visit must occur at a minimum of once every five years. It appears that verifications in the intervening years may be desk verification reviews. During verification, both the fertilizer management plan and a record of the plan as implemented during the project must be made available. There is no required frequency of verification and it may be done in accordance with the projects desire for ERT issuance.

In addition to verification, ACR requires that a third-party ACR-approved verifier "validate" a project against eligibility criteria of the ACR Standard, sector standard and approved methodology. Validation may precede project verification, or the two may occur simultaneously.

As DNDC's model simulation requires a significant number of inputs, such as the location of crop fields, crops grown, local climate, soils, and management practices, 33 inputs are listed in the section on monitored parameters. Parameters are monitored periodically at various frequencies. For some of this data, the project developer may substitute a default or published value (such as for meteorological data). If this approach is chosen, the project developer must choose data conservatively so that it will not over-estimate emission reductions. Monitored data range from recording the planting and harvesting dates, to recording the number of tillage events and the amount and timing of irrigation events. All monitored data "must be archived electronically and retained for at least two years after the end of the project." 16 additional data inputs are required to run the DNDC model. These inputs are either default values or site-specific data points that are measured once at the outset of the project.

Standard operating procedures (SOP) and quality control / quality assurance (QA/QC) mechanisms must be maintained for all field data collection and data management. The ACR recommends following the IPCC AFOLU Guidelines 2006, "national monitoring" procedures, or other similar handbooks.

MSU-EPRI

The MSU-EPRI methodology does not provide detailed guidance on monitoring or verification, as much of this guidance is standardized under the VCS Program and available in the *VCS Standard*. For example, the project developer must prepare a monitoring plan, which includes establishing "a GHG information system for obtaining, recording, compiling and analyzing data and information important for quantifying and reporting GHG emissions and/or removals relevant for the project (including leakage) and baseline scenario," as well as establishes roles and responsibilities.

VCS requires that projects be "validated" to meet eligibility criteria and other VCS rules. "Validation may occur before the first verification or may occur at the same time as the first verification." Typically, AFOLU projects must complete validation within five years of the project start date. Projects with start dates between January 1, 2002 and March 8, 2008 have until March 8, 2013 to be validated.

Prior to undergoing verification, the project developer must prepare and make available the following documentation: "the project description, validation report, monitoring report applicable to the monitoring period and any requested supporting information and data needed to evidence statements and data in the monitoring report." All project documentation and data records must be maintained for at least two years after the end of the project crediting period.

VCS requires that emission reductions are verified to a 5% materiality threshold for most projects, with respect to omission or misstatement concerning reported quantities. However for mega-projects (projects that generate 1,000,000 tCO_2e or more per year), the materiality threshold is one percent. VCS requires a "reasonable" level of assurance, with respect to material errors, omissions and misrepresentations, for both validation and verification. It is unclear whether VCS dictates how frequently verification takes place.

Alberta

While not formally part of verification under the Alberta Protocol, some oversight is undertaken by the Accredited Professional Advisor (APA) who develops and helps the project developer implement the 4R Consistent Plan and must also sign-off on the appropriate implementation of the 4R Consistent Plan for each participating farm. However, the involvement of an APA is explicitly not considered validation or verification for the project and independent, third party verification is still required. It should be noted that while verification is required under the Alberta program, project validation is considered an optional step, which may help inform project design prior to implementation.

A significant amount of data must be monitored and managed while implementing this project. Project Developers are required to maintain project documentation, including all raw data and project calculations for a period of 7 years after the end of the project crediting period. Data are not required to be managed electronically, but all records must be "legible, dated...revised as needed" and maintained in "an orderly manner." To a certain extent, the parameters monitored and the frequency of monitoring depends on the performance level implemented with the project-specific 4R Consistent Plan. Intermediate and Advanced level BMPs require more rigorous monitoring activities. Regardless of BMP level, farm records, aerial photos, GPS data, manure management plans, and data on implementation of the 4R Consistent Plan will be required.

Beyond those components, however, the Alberta protocol itself does not address verification issues specific to fertilizer management, but rather, addresses verification requirements more generally in its Program-wide "Alberta Offset Credit Verification Guidance Document" and the Specified Gas Emitters Regulation. The Alberta program establishes a set of qualifications which must be met by the verifier ("third party auditors"), one of which being that the verifier's conflict-of-interest must be reviewed prior to entering into a contract, and a "Conflict-of-Interest Checklist" must be included in the Verification Statement.

The general materiality threshold for the Alberta Program, to which emission reductions must be verified, is 5%. At present, the Alberta government requires that a "review" or "limited" level of assurance be provided for offset submissions. However, starting in January 2012, a "reasonable" level of assurance will be required.

Under the Alberta Offset Program, according to the "Specified Gas Emitters Regulation, a "compliance report" must be submitted by each regulated facility or Project on March 31, annually, reporting on the previous calendar year's emissions, offsets, etc. As the regulation requires that these annual compliance reports be verified, therefore, it is assumed that verification must also take place annually.