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Agriculture Sector Greenhouse Gas Practices and Quantification Review

Phase 1 Report

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Contents

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Agriculture Sector GHG Practices and Quantification Review

1.0 Introduction

As the landscape for carbon markets and program policy develops, the role for the agricultural sector remains clear. Firstly, the agriculture sector is politically well positioned to influence the development of emission reduction policy to its benefit. Secondly, it is widely understood that there is tremendous opportunity for agricultural sector projects to participate in the carbon markets as supplier of high quality greenhouse gas (GHG) emission offsets. However, there is a lack of consistency and focus around how agriculture projects are functionally going to be included within carbon offset markets.

As the various voluntary and pre-compliance markets for carbon offsets develop, numerous other project types have seen accelerated development of the required understanding and market infrastructure to support continued carbon offset market access. This includes projects such as forestry, landfill gas, biomass diversion from landfill and industrial gases, among others. In contrast, early activity in the agriculture sector towards recognition of GHG emission reduction and sequestration activities, primarily in soil carbon, have largely stalled. The one exception to this may be manure management.

Given the complexity of the biological systems being managed within the agriculture sector, there have been questions about the underlying science of measuring and modeling emission reductions. However, there have been pockets of activity to advance the understanding of these and other issues (i.e. permanence) that support the potential for GHG emission reductions from various changes in agricultural practice types. Consolidation of this activity, and the sharing of the resulting learning, will support broader growth in agriculture sector engagement in the evolving carbon markets.

Increasing the engagement of the agriculture sector in the carbon markets becomes ever more important as we move towards national and regional regulation of greenhouse gas emissions. As these regulatory structures are imposed, there is a likely impact on farm input costs – with offsets providing an opportunity for producers to defray these costs, and even profit from a value being placed on greenhouse gases. Related to the increased agriculture sector engagement in carbon markets is the fact that offset projects generate the infrastructure growers need to facilitate the adoption of GHG mitigating practices. These practices are often in the long-term best interest of the growers' economic outlook, but are commonly not

adopted due to barriers such as culture, perceived risk of yield loss, increased management complexity, lack of advisory services, and a lack of decision support tools, to name some of the more prominent reasons. These infrastructure side benefits serve to both address issues of additionality and act as non-regulatory drivers for agricultural engagement.

To that end, this report, one of two reports under the Market Mechanisms for Agricultural Greenhouse Gases (M-AGG), strives to bring together this work. The goal is not to rank the value of the various initiatives, but rather to highlight the extent of the learning achieved through all of this work. By channeling this activity towards the development of the required carbon market infrastructure, and by communicating the positive results, we hope to support the agricultural sector in accelerating its engagement within the evolving carbon markets.

1.1 About Market Mechanisms for Agricultural Greenhouse Gases (M-AGG)

The Market Mechanisms for Agricultural Greenhouse Gases (M-AGG) was established to provide a high-level bench-marking of the various GHG emission quantification activities within the agricultural sector. Further, M-AGG seeks to focus this review towards supporting the development of robust and rigorous science-based carbon market access mechanisms – GHG emission reduction quantification protocols.

To that end, the M-AGG initiative is divided into two phases. Phase 1 will examine the various quantification tools and methodologies across all agricultural sectors, activities and practices that are currently implemented or nearing implementation[1]. This phase of the project serves to summarize the current state of development with respect to agricultural sector greenhouse gas emission reduction practices, quantification methodologies and protocols. The summary will provide a road-map to stimulate the next phase of carbon market development, and will support various sectors of the agricultural community in benchmarking the current level of activity in their sector relative to others.

Phase 2 will look at the state of the market access mechanisms for carbon sequestration and/or emissions reduction quantifications within the agriculture industry. Phase 2 of this project will serve to further benchmark already developed protocols and quantification methodologies against the larger agricultural sector, broader offset principles, programmatic guidance and best industry standards. The inclusion of this larger perspective will support a greater understanding of the requirements for developing and revising the quantification protocols for GHG emission reductions of various agriculture-related projects for effective implementation.

[1] In North America, and abroad where it may have an impact in North American policy development.

Ultimately, the goal of this project is to encourage the engagement of a broad range of stakeholder groups on the results of the summary and benchmark analysis, leading to a possible third phase. This stakeholder involvement will support an increased capacity across the agriculture and GHG quantification sectors, linking groups across initiatives, and including these groups in effective participation during the USDA and/or USEPA rule-making processes and carbon market infrastructure development.

1.2 Relation of M-AGG to Other Initiatives

Significant consultations have been undertaken to ensure M-AGG collaboration and alignment with the stated goals of a variety of other initiatives. This interaction with complementary related initiatives will continue through the planning and execution of the workshops to link stakeholder groups (market, industry and science communities) and themes (policy, science, and market).

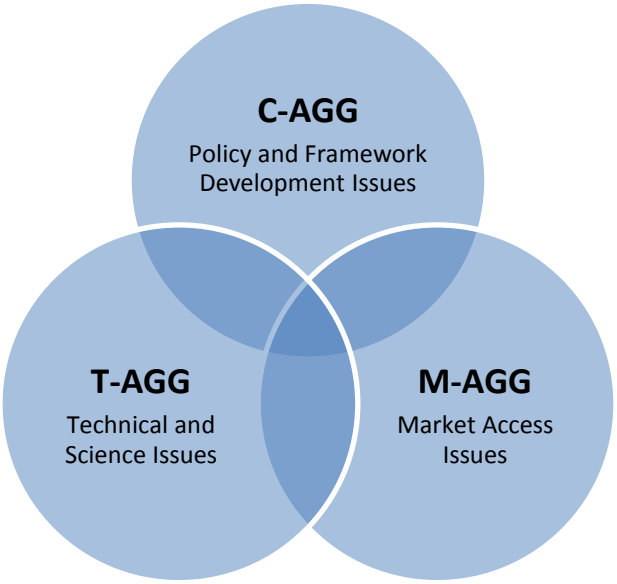

Figure 1.1: Relation of M-AGG, C-AGG and T-AGG Initiatives

The M-AGG project is primarily building from the work of the Coalition on Agricultural Greenhouse Gases (C-AGG) and the Technical Working Group on Agricultural Greenhouse Gases (T-AGG) projects. Each of these initiatives is summarized below.

C-AGG

The Coalition on Agricultural Greenhouse Gases (C-AGG) seeks to mitigate climate change and benefit farmers by advancing the development and adoption of science-based policies, methodologies, protocols, projects and programs for GHG emissions reductions and carbon sequestration within the agricultural sector. C-AGG members include agricultural producers, scientists, GHG quantification experts, carbon investors, policy experts, non-profit representatives, and GHG project developers. C-AGG is primarily a stakeholder forum for constructive engagement and dialogue, cross-pollination of initiatives

and activities, and the development and positioning of supportive policy constructs that incentivize agricultural GHG mitigation activities.

C-AGG's report, "*Carbon and Agriculture: Getting Measurable Results*", was released in April, 2010, and represents contributions from participants in C-AGG, developed in consideration of the diversity of opinions within the Coalition. It is intended to serve as a catalyst for ongoing discussion, and will likely evolve over time as science, data and information improve and evolve, and as new drivers and supportive policy constructs to achieve agricultural mitigation of GHG are identified.

For more information about C-AGG, contact: Debbie Reed, C-AGG Executive Director, at: dreed@drdassociates.org, or visit the C-AGG website at: http:// www.c-agg.org/.

T-AGG

T-AGG brings together technical expertise to assess and assemble the scientific and analytical foundation for developing high-quality agricultural protocols. T-AGG hopes to expand the opportunities for agricultural practices that can mitigate climate change and benefit farmers. T-AGG involves academic experts in agriculture and related fields from across the United States in dialogue with federal agencies, carbon registries, agricultural producers, project developers, and policy experts.

T-AGG will produce a series of reports on key GHG mitigation activities for U.S. agriculture during 2010: a survey and comparison of a wide range of agricultural practices that can provide a road map for future protocol and policy development; and in depth reports to guide protocol development for two promising agricultural activities – soil carbon management and nitrous oxide emissions reduction on cropland.

For information about T-AGG, advisers, experts, outlines, drafts and reports, please visit the T-AGG website at: http://www.nicholas.duke.edu/institute/t-agg/, or contact Lydia Olander, T-AGG Project Director, at Lydia.olander @duke.edu.

The M-AGG project takes off from the current work of the C-AGG group, as it extends the results of the collaborative process into the minutiae of carbon market infrastructure development. Continued linkage to the C-AGG group will ensure on-going collaboration through the bridging of initiatives and timing the third-phase workshops with C-AGG meetings. The T-AGG project from the Nicholas Institute and the M-AGG project have a particularly synergistic relationship, since the M-AGG project is focusing on the existing quantification infrastructure and the markets they are set to support, and the T-AGG is filling the technological gaps for future development. Acting to ensure ongoing collaboration of these two complementary projects, the initiatives contributed to knowledge-sharing through active participation of lead members of M-AGG within in both the C-AGG and T-AGG projects.

2.0 Objectives of Phase 1 – Agriculture Sector GHG Practices and Quantification Review

Phase 1 of the study examines the available quantification tools, and the practices therein, that are being used and/or developed for use in agricultural greenhouse gas assessments. The many types of quantification tools vary considerably in scope, approach, scientific underpinnings and purpose for which they should be applied. In this Phase of the report, we seek to classify and characterize these tools, and the agricultural activities or practices they cover, to give the reader a sense of where these tools differ, and why some of these tools serve as carbon market access mechanisms, whereas others are more suited for other purposes. The intent is to bring clarity to the discussion.

2.1 Activities and Deliverables

To review the current state of development of quantification tools for agriculture GHG practices and assess which ones are 'protocol or market ready', a series of activities were undertaken:

- Researching available quantification tools, methods, protocols and identify the agricultural sectors, activities and practices, and emission reduction pathways offered by each;
- Classifying the tools into general categories, as well as the activities/practices to facilitate characterization;
- Characterizing the quantification tool and associated activities against three general pillars, each with their own set of criteria (explained in Section 3 below):
    - Scope and framework of the tool
    - Scientific basis and general approach
    - Development process and inputs; and,

- Passing the tools through a 'Protocol Filter' or set of criteria common to market access mechanisms worldwide.

The deliverables for this Phase of the study include a compiled matrix that catalogues the classes of tools along with their accompanying analysis, benchmarked against the characterization criteria. Further, a sub-set of the above will be identified as 'carbon market access mechanisms' and will pass along to the next Phase of the study.

The results of the matrix and this report will serve as one of the main pieces of communication to the stakeholder communities through the workshops and follow-up initiatives.

2.2 Common nomenclature on quantification protocols/methodologies

As the policy landscape for carbon markets continues to develop in the U.S., there is a need for common nomenclature between the various programs, initiatives, regional frameworks and independent tool developers to facilitate understanding of carbon market accounting. We have found that as these groups proceed in their work, terms and language in one group can mean something entirely different to another. This is to be expected since the field of defining carbon offsets necessarily requires multi-disciplinary knowledge-sets, often between economists, scientists, environmentalists, sectoral practitioners, accountants, engineers and policy-makers. But, it can be very confusing to those participating in the process.

For this reason, this report will use a common nomenclature around GHG standards, programmatic guidance, quantification protocols and quantification methodologies to help frame the technical and policy context of this work (Figure 1). This nomenclature is derived from the carbon market infrastructure of functioning offset programs and markets around the world.

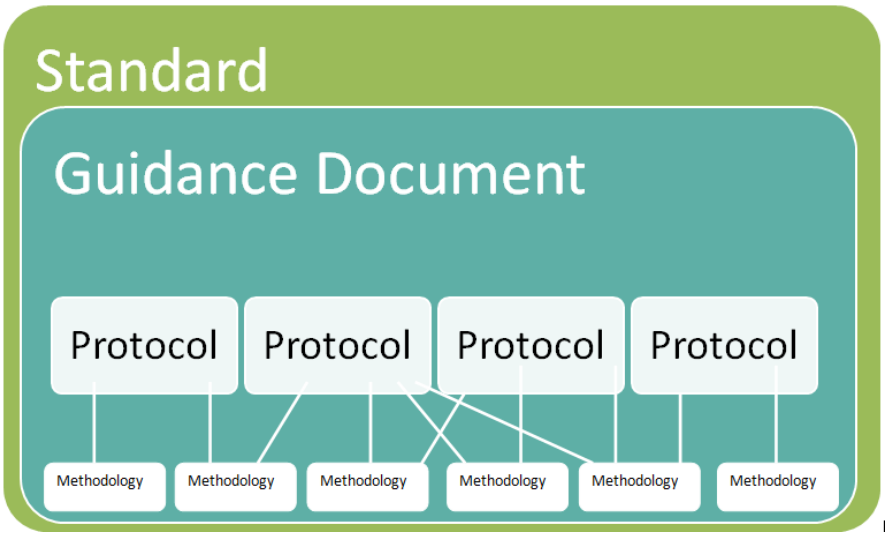

Figure 2.1. The relationship among standards, guidance documents, protocols and methodologies applied in this report.

GHG Standard - a process-based document that specifies requirements and principles of accounting for project-based reductions. Examples include the ISO 14064-2 Standard (*http://www.iso.org/iso/catalogue_detail?csnumber=38381)* and the WRI GHG Protocol Standard for project accounting (*http://www.ghgprotocol.org/files/ghg_project_protocol.pdf)*. These standards are typically regime-neutral and can be adopted by relevant companies, organizations and/or governments, to provide consistency and confidence in the measurement, reporting and verification (MRV) of GHGs for the Program and Policy rules of the particular GHG framework. *Standards* cover project accounting details including guidance on what gases should be counted, what the different kinds of baseline scenarios are and the procedures to assess the appropriate baseline, how measurement uncertainties should be addressed, functional equivalence, managing data quality, how to set boundaries for measurement and monitoring, addressing leakage of GHG impact outside those boundaries, and quantifying reversals. They also address requirements for monitoring, documentation, reporting, and verification of projects.

GHG Program Guidance Document – a document containing the rules for applying the above GHG standards to the particular system at hand. It covers the jurisdictional criteria and requirements for developing protocols, projects, and programs for GHG mitigation under a particular jurisdiction or organization (e.g., Voluntary Carbon Standard or VCS). They are designed to ensure that protocols, and sometimes resulting projects and programs, meet specific policy criteria for the system's offsets definition, and sets minimum measurement,

verification, and reporting (MRV) procedures to qualify under a particular jurisdiction, agreement, or registry. Examples include the VCS AFOLU (*http://www.v-c-s.org/afl.html)*; WRI LULUCF (*http://www.ghgprotocol.org/files/lulucf-final.pdf*); or Canada's draft Technical Guidance for the Offset System (out for comment). These documents can be supported by measurement guidance offered by the IPCC Good Practices Guidance (*http://www.ipcc-nggip.iges.or.jp /public/gpglulucf/gpglulucf.html*). Guidance documents are not intended to "teach" project developers. It needs to become a stated criterion of GHG offset programs that project developers should be equipped with the necessary knowledge and expertise to address the particular area(s) of focus within a protocol. Project developers are expected to have practical and technical expertise in the practices prescribed by a protocol as well as a comprehensive understanding of the science of the environmental processes underlying the technology or practices for GHG mitigation.

GHG Quantification Protocol – a document, typically approved by a regulator/program manager, that outlines the necessary procedures for developing an offset project including all relevant rules, procedures, parameters, equations, and deductions for the offset credit accounting process. These are often in the form of separate methods or modules, including detailed information on the measurement methodology, project data monitoring, reporting and verification (MMRV) of GHG emission reductions/removals for a particular project type. Protocol development is a credentialed process and regulators/program managers typically expect transparency in development with well-documented technical input and review. Standardized protocols are designed to be used by different, yet similar project-types to eliminate the development costs associated with the intricate review process required for personalized project protocols. They also provide consistency in the necessary criteria for verification – reducing the costs of verification of GHG projects.

GHG Quantification Methodology – the measurement technique(s) used by the protocol for different aspects of a project. These may include specific tools, such as empirical models, process-based models and rules for how they are used, or field measurement/sampling procedures, that sit within a protocol. For example a protocol would include *methods* for each of the following: estimating baseline, quantifying carbon sequestered in soils, quantifying reversals if needed, estimating discounts for leakage potential, or determining buffer size for reversal risk.

3.0 Quantification Tool Identification and Classification

Agriculture sector GHG quantification tools are constantly under development and refinement. For the purposes of this report, assessment tools were restricted to those currently in use, and

those on the cusp of being released for use by the general public. A broad, high-level scan of the currently available quantification tools was completed for this report – seeking the widest possible range of sources. Although not likely exhaustive, this list is intended to be indicative and revised in subsequent drafts.

3.1 Classification Criteria

To gain a general understanding of the GHG quantification approaches used in available calculators, LCA analyses, quantification methodologies, models, protocols and standards, generic classification criteria have been established. This classification process includes four main categories:

1. Generic descriptions, as per the review of the quantification tool.
2. Assignment of tool type and sub-type, as per the definitions provided in Table 3.1, below.
3. Listing of the covered areas of agricultural activity as per the definitions provided in Table 3.2, below. The following management areas were listed as agricultural activities for general tool classification: Soil Management, Crop Management, Nitrogen Management, Land Use Management, Livestock Management and Residues/Waste Management.
4. Applicable greenhouse gases covered in the models. The relevant GHGs within the agriculture sector primarily consist of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). As such, all tools have been assessed to determine their coverage across the range of GHGs – considered as 'GHG Inclusiveness'. Tools that include the full range of GHG inclusiveness will be better able to accurately represent total emissions and emission reduction or mitigation strategies available to agricultural operators.

Table 3.1: Quantification Tool Typology

Tool Type	Sub-Type	Description
Measurement Techniques	Empirical Model	A set of rules/equations, based on empirical observations that calculate the GHG impacts of a system.
	Process-based Model	Based on mathematically describable bio-geochemical relationships of the GHG dynamics of the system modeled.
	Field-Based Sampling	Measuring GHG impacts using statistical sampling and analytical procedures (soils, flux measurements, remote sensing, or chamber methods) at the field or landscape scale.
	Hybridized Techniques	Any combination of the above.
Calculator	Decision Support System Planning Tool	Typically used for planning; contains a set of modularized computations for assessing the impact of a practice/activity on GHG emissions. Rarely are there reciprocal feedback loops between modules for net accounting of GHGs.
Quantification Protocol	Performance Standard Certification Standard CDM Methodology	A protocol includes all relevant rules, parameters and equations for the components of GHG accounting process *(*estimating baseline, quantifying GHG emissions, removals or reversals; estimating discounts for leakage potential, or determining buffer size for reversal risk; monitoring procedures).
LCA or Carbon Footprinting	LCA	Assessment of environmental impacts of a good or service – GHGs (1 or more), water, energy, nutrient use. Typically used for strategy development, benchmarking, informing, indicating, measuring and/or market branding. Depth and breadth of LCAs can vary depending on the scope and system boundary; ISO 14040 is one of the Standards.
	Carbon Footprinting	Greenhouse gas emissions from a company's business operations, event, activity or product lifecycle – may be one gas (CO_2 or N_2O or CH_4 or all…); scope and system boundary may vary. ISO 14067 Draft International Standard

Table 3.2: Areas of Agricultural Activity

Area of Agricultural Activity	Mitigation Activity	Subsets of Activity
Soil Management	Conservation Tillage (CT)	No-till, Strip-till, Ridge-till
	Residue Management	Increased residue retention; soil amendments
	Fallow Management	Increased conversion to continuous cropping
	Management of Organic Soils	Avoiding cultivation/fertilization
Crop Management	Conversion to Perennial Forage	Annual to perennial crops (land use change); Increase in rotations (within an annual cropping system; a few years of a perennial); Short rotation biomass crops.
	Irrigation Improvements	Increased water and energy use efficiency
	Reducing Chemical inputs	Displacing fossil fuel-based inputs (legumes, manure, pesticides); Relying on biological sources of N or biological control of pests
	Cropping Strategies	Cover crops; crop rotation
	Afforestation	Inter-cropping; planting trees, shelterbelts
	Rice Cultivation	Altered paddy flooding; Residue management; New varieties
N Management	Increased Fertilizer N Use Efficiency	Right form, right time, right place, right rate of fertilizer application (via soil testing) (4 R's; individual or combined); Landscape variability; Slow release fertilizer; Split application; Nitrification inhibitor
	Increased Manure Use Efficiency	Agronomic applications – reducing the amount applied (Soil/manure testing); timing and application type Processing manure to concentrate/stabilize nutrients
Land Use Management	Drainage of agricultural lands in humid areas	Facilitating sub-surface drainage in agricultural fields for cropping purposes. (e.g. tile drainage)
	Buffer Strips	Riparian buffers; shelterbelts; grassed waterways
	Wetlands Management	Restoration or Conservation
	Land Conversion	Grazing Lands; Conservation Reserves

Area of Agricultural Activity	Mitigation Activity	Subsets of Activity
Livestock Management	Ruminant Feeding Strategies	Increasing feed efficiency (reduced GHGs per kg beef, litres of milk); Genetics, diet modification/feed additives (edible oils or ionophores, distillers grains; increased concentrates); reducing lifespan of cattle; Grazing management
	Manure Management	Methane Avoidance (emptying lagoons before hot summer months); Anaerobic digesters; methane capture and destruction; solid-liquid separation
Residues/Waste Management	Biomass to Energy Biofuels Biogas	Dedicated biomass crops (woody or vegetative); Liquid fuels (grain/oilseeds/cellulosic – 1st generation and 2nd generation)
Farm Energy Management	Vehicle Management,	Fuel Efficiency (fuel types, maintenance), Vehicle Use (passes/trips, loading);
	Facilities Management	Housing/Storage (animals, products, outbuildings, refrigeration, energy efficiencies), Operations (food distribution, feedlot management, processing, packaging), Energy Efficiencies

3.2 Classification of Quantification Tools

Based on the criteria outline in Section 3.1, the quantification tools are identified and classified in Tables 3.3 and 3.4. In Table 3.3, these tools are sorted by name. In Table 3.4, these tools are sorted by area of agricultural activity. Tool reference or resource information is located in Appendix A.

Table 3.3 Agricultural Activities and Their Associated Quantification Tools

Agricultural Activity	Tool
Soil Management	AOS Tillage APEX Australian Farm GAS Carbon Trust CASA Express or CASA CQUEST CCX -- Agricultural Best Management Practices CLA CALM COMET-VR/ -FARM Cool Farm Tool DAYCENT/ CENTURY DNDC/ DNDC NUGGET FAO Carbon ExACT Holos RothC VCS Grassland Management

Agricultural Activity	Tool
Crop Management	ACR Forest Carbon APEX Australian Farm GAS Beauchemin et al. 2010 Biswas et al 2008 CAR -- Forest Project Protocol Carbon Trust CASA Express or CASA CQUEST CCX -- Agricultural Best Management Practices CCX -- Forestry Carbon Sequestration CDM (small-scale) -- III.A. CLA CALM COMET-VR/ -FARM Cool Farm Tool DAYCENT DMI 2007 DNDC/ DNDC NUGGET FAO 2010 Dairy FAO Carbon ExACT Field to Market Holos Millar et al. 2010 Pelletier 2008 Pelletier et.al., 2010 Peters et al 2010. RGGI --Afforestation RothC VCS -- Afforestation/ Reforestation VCS - SALM Vergé et al. 2008 Vergé et al. 2009 Williams et al. 2006

Agricultural Activity	Tool
Nitrogen Management	ACR Fertilizer Management (UNDER REVIEW FOR APPROVAL) AOS NERP (UNDER REVIEW FOR APPROVAL) APEX Australia Farm GAS Biswas et al 2008 Carbon Trust CASA Express or CASA CQUEST CLA CALM COMET-VR/ -FARM Cool Farm Tool DAYCENT DMI 2007 DNDC/ DNDC NUGGET FAO Carbon ExACT Field to Market Holos Millar et al. 2010 VCS MSU-EPRI N2O
Land Use Management	ACR Forest Carbon APEX Australian Farm GAS Carbon Trust CASA Express or CASA CQUEST CLA CALM COMET-VR/ -FARM Cool Farm Tool DAYCENT DNDC/ DNDC NUGGET FAO Carbon ExACT Holos VCS - SALM

Agricultural Activity	Tool
Livestock Management	ACR Livestock Manure Management AOS Beef Feeding (Edible Oils) AOS Beef Feeding (Reducing Days-on-Feed) AOS Beef Lifecycle AOS Biogas AOS Dairy Cattle Emission Reduction AOS Pork APEX Australian Farm GAS Beauchemin et al. 2010 CAR -- Livestock Project Protocol CASA Express or CASA CQUEST CCX -- Agricultural Methane Collection and Combustion CCX -- Sustainably Managed Rangeland Soil Carbon Sequestration CDM -- ACM0010 Manure Management CLA CALM COMET-VR/ -FARM Cool Farm Tool DMI 2007 DNDC/ DNDC NUGGET FAO 2010 Dairy FAO Carbon ExACT GHGS Holos Pelletier 2008 Pelletier et.al., 2010 Peters et al 2010 RGGI -- Manure Management VCS ALM Grassland Management Vergé et al. 2008 Vergé et al. 2009 Williams, et al. 2006

Agricultural Activity	Tool
Residues/ Waste Management	CAR -- Livestock Project Protocol CCX -- Agricultural Methane Collection and Combustion GHGS VCS - SALM
Farm Energy Management	ACR Fertilizer Management (UNDER REVIEW FOR APPROVAL) ACR Livestock Manure Management AOS Energy Efficiency Quantification Protocol AOS Tillage Quantification Protocol Australian Farm GAS Beauchemin et al. 2010 Biswas et al 2008 Carbon Trust CLA CALM COMET-VR/ -FARM Cool Farm Tool DMI 2007 FAO 2010 FAO Carbon ExACT Field to Market Holos Pelletier 2008 Peters et al 2010 Vergé et al. 2008 Williams, et al. 2006

Table 3.4 General Description of Quantification Tools

Tool	Description	Agricultural Activity	Tool Type	GHG Category
ACR Fertilizer Management (UNDER REVIEW FOR APPROVAL)	Fertilizer emission reduction methodology involving a change in fertilizer management. The protocol involves a comprehensive fertilizer use reduction approach following the 4-R strategy as well as a regard for landscape variability and use of nitrification inhibitors. Calculations involve the use of the DNDC model, and follow methods from the GPG—LULUCF, GPG-2000, IPCC Revised 2006 Guidelines and those from the CDM Executive Board.	Nitrogen Management, Farm Energy Management	Quantification Protocol	N2O, CO2, CH4
ACR Forest Carbon	Forest carbon-based greenhouse gas emission reduction and removal project standard focusing on Afforestation and Reforestation (AR), Improved Forest Management (IFM) and Reducing Emissions from Deforestation and Degradation (REDD). Applicable to projects in the USA and other nations starting on or after 1 November 1997, with a minimum project term of 40 years. Reporting and monitoring allows use of EPA Climate Leaders, CDM, IPCC and VCS assessment methodologies.	Crop Management, Land Use Management	Quantification Protocol	CO2
ACR Livestock Manure Management (UNDER REVIEW FOR APPROVAL)	Manure management emission reduction methodology for the installation of biogas control systems (i.e. anaerobic digesters) for methane capture and destruction, as well as the reduction of other GHG emission releases (CO2 and N2O) from dairy and swine operations. Applicable to projects in the USA starting on or after 1 January 2000. Calculations include tools and methodologies from ERG, USEPA, CDM, USDA, and IPCC.	Livestock Management, Farm Energy Management	Quantification Protocol	CH4, CO2, N2O, [NH3 provides for counting, does not give ERT credit]

Tool	Description	Agricultural Activity	Tool Type	GHG Category
AOS Beef Feeding (Edible Oils) (UNDER REVIEW)	Feedlot offset accounting protocol for Alberta operations to quantify enteric emission reductions based on diet modification to include edible oils. The protocol assesses CH4 emission reductions where edible oils make up 4-6% of the finishing diet. Data on diets is required for calculations following IPCC best practice guidance with expert-validated emission factors.	Livestock Management	Quantification Protocol	CH4
AOS Beef Feeding (Reducing Days-on-Feed) (UNDER REVIEW)	Feedlot offset accounting protocol for Alberta-based operations, quantifying enteric CH4 and manure management CH4 and N2O emissions. It involves diet modification and feed additives to decrease days-on-feed required for equivalent cattle weight gain. The protocol uses IPCC best practice guidelines and expert-validated emission factors.	Livestock Management	Quantification Protocol	CH4, N2O
AOS Beef Lifecycle (UNDER REVIEW)	Offset accounting protocol for full lifecycle cattle management in Alberta operations, to maintain production while reducing cattle lifespan duration. The protocol assesses enteric CH4 and manure CH4 and N2O emissions, requiring extensive data management with respect to full-lifecycle diet parameters. Offset calculations are based off of IPCC best practice guidance and expert-validated emission factors.	Livestock Management	Quantification Protocol	CH4, N2O
AOS Biogas	Anaerobic digester offset accounting protocol for Alberta-based projects using manure and other organic feedstocks. The protocol accounts for biogas production used for electricity, biofuel and heat/power generation. CO2, CH4 and N2O emissions quantifications are based on IPCC guidance and approved emission factors from landfill avoidance to attribute full emission reduction value.	Livestock Management	Quantification Protocol	CO2, CH4, N2O

Tool	Description	Agricultural Activity	Tool Type	GHG Category
AOS Dairy Cattle	Alberta dairy farm offset accounting protocol to increase annual per-cow milk production, reducing emissions per unit of milk produced. The protocol includes diet modification and additives, a reduction in heifer herd size, as well as altered manure management strategies to reduce enteric emissions. The quantifications follow IPCC best practice guidance with expert-validated emission factors and either a basic or an advanced direct measurement emission reduction quantification approach.	Livestock Management	Quantification Protocol	CO2, CH4, N2O
AOS Energy Efficiency	Facilities management and energy efficiency offset accounting protocol for a broad range of projects on farms and other industrial, commercial and institutional facilities. CO2, CH4 and N2O emission reductions from fossil fuel and electricity usage are included, and are applicable across a broad range of farm facilities. Emission factors are taken from (IPCC) best practice guidance, while measurement and modeling techniques are largely based on (IPCC) first principles.	Farm Energy Management	Quantification Protocol	CO2, CH4, N2O
AOS NERP	Nitrogen emission quantification protocol based on the implementation of comprehensive nitrogen manage-ment plans for optimum crop nitrogen uptake following a 4-R approach for crop system nitrogen management. The protocol follows IPNI beneficial management practices.	Nitrogen Management	Quantification Protocol	N2O
AOS Pork (UNDER REVIEW)	Offset accounting protocol for Alberta swine operations to address manure-based emissions. The protocol includes diet modification, feed additives, and methane avoidance to quantify CH4 and N2O manure emission reductions. The protocol uses IPCC best practice guidance and emission factors validated by experts.	Livestock Management	Quantification Protocol	CH4, N2O

Tool	Description	Agricultural Activity	Tool Type	GHG Category
AOS Tillage	Offset accounting protocol for improved tillage practices on Alberta cropland for farms implementing conservation tillage practices. The protocol quantifies CO2, CH4, and N2O emission reductions from energy use and soil sequestration from land under certain tillage practices within specified ecoregions. The project start date includes an adjusted baseline approach, discounting values for practice prevalence in 2001. Quantification calculations use the Century model for no-till and reduced-till sequestration factors.	Soil Management, Farm Energy Management	Quantification Protocol	CO2, CH4, N2O
APEX - Agricultural Policy Environmental eXtender	Process-based model assessing complete C and N cycles, C and N storage, nutrient loading and losses through volatilization. Also assesses CO2 sequestration via plant growth. Based off of algorithms from EPIC, and concepts from CENTURY calculations. Can be used for daily time step calculations or long term simulations (1 to 4000 years).	Soil Management; Crop Management; Nitrogen Management; Land Use Management; Livestock Management	Process-based model.	Soil nutrient (C and N) stocks, CO2 and N volatilization.
Australian Farm GAS Calculator	Assesses CO2, CH4 and N2O emissions from management for livestock production, cultivation and land use changes, and the application of fertilisers to farmlands within Australia.	Soil Management, Crop Management, Nitrogen Management, Land Use Management, Livestock Management, Farm Energy Management	Calculator	CO2, CH4, N2O calculated as CO2e

Tool	Description	Agricultural Activity	Tool Type	GHG Category
Beauchemin et al. 2010 Western Canadian Beef	LCA assessing beef production in Western Canada, encompassing N2O, CH4, and CO2 produced during upstream fertilizer and pesticide manufacturing, on-farm crop and pasture management, animal feeding, feedlot management, manure handling and storage and meat production to farm gate. The LCA uses calculations from HOLOS as the basis for analysis.	Crop Management, Livestock Management, Farm Energy Management	LCA	N2O, CO2, CH4
Biswas et al 2008 Australian Wheat	LCA to assess global warming potential of wheat production in Western Australia. Covers pre-farm GHGs from machinery, fertilizer and pesticide manufacturing, on-farm vehicle use during crop management, and post-harvest grain distribution and transportation.	Crop Management, Nitrogen Management, Farm Energy Management	LCA	CO2, N2O
CAR - Forest Project Protocol	Offset accounting protocol for reforestation/ afforest-ation projects on lands with less than 10% tree canopy for at least 10 years prior. Activities can occur on public or private lands.	Crop Management	Field-based Sampling	CO2, Soil C-sequestration, Biomass
CAR - Livestock Project Protocol	Offset accounting protocol for farms in the USA to avoid methane emissions from stored livestock manure, using a capture and destruction method with potential for the beneficial use of biogas. Applicable to farms raising livestock in confined conditions using a liquid or slurry system for manure management.	Livestock Management, Residue/ Waste Management	Quantification Protocol	CH4
Carbon Trust Carbon Footprint Calculator	Carbon footprint calculator intended for crop production in the UK, and thus to include agriculture in a full carbon footprint calculation.	Soil Management, Crop Management, Nitrogen Management, Land Use Management, Farm Energy Management	Footprint Calculator	CO2 emissions only. Soil carbon is excluded from accounting.

Tool	Description	Agricultural Activity	Tool Type	GHG Category
CASA Express or CASA CQUEST	Tier 3 model using remote sensing with an easy-to-use ArcGIS interface, and background calculations based on user-provided data, satellite imagery and remote sensing data, and IPCC baseline information. Scalable to the 1/4 acre, as well as region and nation. Useable world-wide.	Soil Management, Crop Management, Nitrogen Management, Land Use Management, and Livestock Management (as it pertains to grazing)	Process-based model.	N2O, CH4, CO2; some NH4 and NO in California
CCX - Agricultural Best Management Practices	Offset accounting protocol to improve soil C sequestration through conservation tillage (no-, strip-, zero-, slot- and zone-till), as well as direct seeding and cropland-to-grassland conversion. Designed for implementation on Land Resource Regions across the USA with different eligibility dates depending on whether tillage or grassland conversion projects.	Soil Management and Crop Management	Quantification Protocol	CO2, Soil C-sequestration
CCX - Agricultural Methane	Offset accounting protocol to avoid methane emissions from stored manure, using capture and destruction practices. Projects must occur in the USA or non-Annex 1 countries, as listed by the Kyoto Protocol.	Livestock Management, Residue/ Waste Management	Quantification Methodology using Field-based Sampling and Empirical Models	CH4
CCX - Forestry Carbon Sequestration	Afforestation offset accounting for projects within the USA or non-Annex 1 countries, where previously non-forested land (at least 10 years prior) is planted to have trees on more than 0.5 ha, with potential or current canopy height greater than 5m and canopy cover greater than 10%.	Crop Management	Quantification Protocol	CO2, C Sequestration, biomass; excludes N2O

Tool	Description	Agricultural Activity	Tool Type	GHG Category
CCX - Sustainably Managed Rangeland	Offset accounting protocol for improved rangeland management through formal grazing plans on rangelands within Land Resource regions of the USA that are privately, state, or tribally owned. In order to qualify, rangelands must not be fertilized or irrigated.	Livestock Management	Quantification Protocol	CO2, Soil-C Sequestration
CDM -- ACM0010 Manure management systems	Offset accounting methodology generally applicable to livestock farm manure management to capture and destroy methane from stored manure. Applicable for farms where existing anaerobic treatment system is replaced by one or more AWMS (Animal Waste Management Systems) resulting in lower GHG emissions.	Livestock Management	Quantification Protocol	CH4
CDM (small-scale) -- III.A. Nitrogen Fertilizer Offset	Offset accounting methodology to inoculate soybeans with rhizobium bacteria adapted to acidic soils. Methodology to be used on grass-legume cropping rotation systems on low pH (<5.5) soils where no previous inocula were used as a means to reduce fertilizer N inputs.	Crop Management	Quantification Methodology	N2O, NOx, CO2, CH4
CLA CALM	Calculator assessing emissions from farm energy and fuel use, livestock production, cultivation and land use changes, and the application of fertilisers to farmlands within the United Kingdom (Great Britain, Wales, Scotland and Northern Ireland).	Soil Management, Crop Management, Nitrogen Management, Land Use Management, Livestock Management, Farm Energy Management	Calculator	CO2, CH4, N2O

Tool	Description	Agricultural Activity	Tool Type	GHG Category
COMET-VR/ - FARM	The Voluntary Reporting of greenhouse gases - Carbon Management Evaluation Tool (COMET-VR) is a Decision Support Tool to aid agricultural producers, land managers, soil scientists and others in making management changes. It models current and previous farming activities and the likely soil carbon sequestration/emissions from changes to current activities, based on past management. Real-time annual carbon flux calculations are based on access to the Carbon Sequestration Rural Appraisal (CSRA) database, using a dynamic Century model simulation. Results are presented as ten-year averages of soil C sequestration or emissions with associated uncertainty values.	Soil Management, Crop Management, Nitrogen Management, Land Use Management, Livestock Management, Farm Energy Management	Calculator/ Decision Support Tool linked to a process model	Soil carbon only at present. N2O estimation is in the works.
Cool Farm Tool	Calculator to estimate the current carbon footprint of "each farming system being evaluated"	Soil Management, Crop Management, Nitrogen Management, Land Use Management, Livestock Management, Farm Energy Management	Calculator	N2O, CH4, CO2

Tool	Description	Agricultural Activity	Tool Type	GHG Category
DAYCENT/ CENTURY	Biogeochemical model, with underlying equations based on regressions from N2 and N2O flux observations in soil cores. DAYCENT simulates exchanges of carbon, nutrients and trace gases among the atmosphere, soil and plants. Flows of C and nutrients are controlled by the amount of C in the various pools, the N concentrations of the pools, abiotic temperature/soil water factors, and soil physical properties related to texture. Beginning in 2005, DAYCENT has been used to estimate N2O emissions from cropped and grazed soils for the US National GHG Inventory. The model is also used to investigate how land use and climate change impact plant growth and soil C and N fluxes.	Soil Management, Crop Management, Nitrogen Management, Land Use Management	Process-based model.	N2O, (model may also be used to predict N2O, CO2, CH4, NOx, N2 as net greenhouse gas fluxes for various scenarios and systems to the year 2100)
DMI 2007 Dairy	Carbon Footprint analysis assessing dairy sector (fluid milk) in USA. High-level scan footprint analysis only, to assess fertilizer manufacturing, cropping strategies, pasture production, livestock feeding strategies, manure handling, milk and meat production, processing, packing, distribution and retail, and all associated transportation.	Crop Management, Nitrogen Management, Livestock Management, Farm Energy Management	Scan-level Footprint Analysis	N2O, CH4, CO2
DNDC	"DeNitrification and DeComposition" model. Process-based model framework reflecting soil carbon and nitrogen dynamics under conditions imposed by different management. Soil rate constants vary by abiotic factors of soil moisture, temperature and texture. To relate C and N cycles, the output of soluble C drives denitrification	Soil Management, Crop Management, Nitrogen Management, Land Use Management, Livestock Management	Calculator/ Decision Support Tool	N2O, NO3, NOx, N2, CH4, and CO2.

Tool	Description	Agricultural Activity	Tool Type	GHG Category
DNDC NUGGET	Calculator application of DNDC model. (See description of DNDC above) *DNDC and DNDC NUGGET will be listed as one for all other tables in this document.	Soil Management, Crop Management, Nitrogen Management, Land Use Management, Livestock Management	Calculator	N2O, NO3, NOx, N2, CH4, and CO2 modeled. Assesses cropping systems (including rice CH4), grazing systems and manure application/management. Nitrate leaching loss (NO3) also included. Soil carbon sequestration, crop development and biomass yields.
FAO 2010 Dairy	LCA to assess GHG emissions from dairy sector (anywhere globally). Analysis extends to upstream fertilizer and pesticide manufacturing, pasture management, dairy feeding strategies, manure handling and storage, milk and meat production and processing and transportation. LCA includes GHG costs of deforestation for dairy production and transport from farm to dairy to retailer.	Crop Management, Livestock Management, Farm Energy Management	LCA	N20, CH4, CO2
FAO EX-ACT	Calculator to assess GHG emissions from the agricultural sector (anywhere globally). Analysis enables use of default IPCC or user-defined values. Includes GHG costs of wide variety of agricultural activities from cropping systems to afforestation to land use changes, to livestock management.	Soil Management, Crop Management, Nitrogen Management, Land Use Management, Livestock Management, Farm Energy Management	Calculator	CO2, NO2, CH4

Tool	Description	Agricultural Activity	Tool Type	GHG Category
Field to Market Keystone Alliance	Supply-chain system of agricultural sustainability to decrease N2O emissions by increasing fertilizer use efficiency and decrease CO2 emissions by increasing fuel efficiency and reducing agricultural chemical inputs and application. For use on corn, cotton, soybean and wheat farms	Crop Management, Nitrogen Management, Farm Energy Management	Measurement Technique	N2O, CO2, C-sequestration
GHGS Livestock Manure Management	Offset methodology for manure-derived methane capture and destruction on farms in the USA raising livestock in confined conditions with a liquid or slurry manure management system. Allows for the beneficial use of captured CH4, but does not generate "displacement" credits for this activity	Livestock Management, Residue/ Waste Management	Quantification Protocol (using empirical models and field-based sampling)	CH4, CO2
Holos	Whole-farm modeling program based on farmer input and algorithms using Canadian-condition-modified IPCC Tier 1 and Tier 2 approaches. Follows a yearly time-step.	Soil Management, Crop management, Nitrogen Management, Land Use Management, Livestock Management, Farm Energy Management	Calculator and decision support tool	N2O, CH4, CO2
Millar et al. 2010 N2O in Corn	Fertilizer over-application avoidance via crop rotation, reduced N-Fertilizer application and credit trading.	Crop Management, Nitrogen Management	Quantification Methodology	N_2O
Pelletier 2008. Broiler Poultry	LCA to assess broiler poultry production in USA from upstream fertilizer and pesticide manufacturing, to on-farm feed production, to manure/litter handling and storage, and facility energy use. Assesses the production of CH4, N2O, CO2, Ozone Depleting Substances, nutrients like P and N, and acidifying and eutrophying substances.	Crop Management, Livestock Management, Farm Energy Management	LCA	N2O, CH4, CO2, other gases and nutrients like P and N, as well as Ozone Depleting Substances.

Tool	Description	Agricultural Activity	Tool Type	GHG Category
Pelletier et.al., 2010 Beef LCA comparison	Comparison of LCA results on 3 different beef production systems to identify areas of inefficiency. The comparison assesses whole-scale upstream production through to farm-gate live-weight beef production. Assessment focuses on different feeding strategies and resulting weight production and enteric fermentation emissions.	Crop Management, Livestock Management	Comparison of three LCAs	N2O, CH4, CO2, other gases and nutrients including P and N.
Peters et al 2010 Red Meat LCA in Australia	LCA assessing red meat production (beef and sheep) in Australia. Analysis includes upstream fertilizer and pesticide manufacturing, on-farm crop management, pasture production, feeding strategies, manure handling and storage, and meat production. The assessment also includes all energy for farm feedlot management, processing and associated transportation. LCA suggests changes to Livestock Management approaches.	Crop Management, Livestock Management, Farm Energy Management	LCA	N2O, CH4, CO2
RGGI - Manure Management	Methane emission avoidance through capture and destruction from stored livestock manure. Accounting includes management of organic food wastes as long as manure comprises at least 50% of annual mass. Applicable to RGGI member states in USA, but may be adaptable to other jurisdictions using US national inventory approach.	Livestock Management	Quantification Methodology	CH4, excludes N2O
RGGI - Afforestation	Offset accounting for afforestation projects using native tree species with the intent of promoting the restoration and sustainable management of native forests where lands have not been forested for at least 10 years prior.	Crop Management	Quantification Methodology	C Sequestration
RothC Soil Carbon	Process-based model assessing soil carbon fluctuations using monthly time step climate, soil, plant and manure data for up to centuries-long carbon trend projections.	Soil Management, Crop Management	Process-based model.	Soil carbon and nitrogen

Tool	Description	Agricultural Activity	Tool Type	GHG Category
VCS - Afforestation/ Reforestation (UNDERGOING ASSESSMENT)	Afforestation offset accounting methodology intended to provide guidance for future afforestation methodologies so that approval of future methodologies does not require validation. Tree planting on land with no trees in previous 10 years, displacing crops, grazing and/or fuel wood production.	Crop Management	Quantification Protocol	CO2, biomass (changes in organic carbon pools)
VCS ALM Grassland Management (UNDERGOING ASSESSMENT)	Sustainable grassland management carbon sequestration quantification protocol for un-fertilized, un-cultivated grasslands that may be managed with the use of fire for livestock and/or wildlife grazing purposes.	Soil Management, Livestock Management	Quantification Protocol	CO2, N2O, CH4
VCS -SALM Agricultural Land Management (UNDERGOING ASSESSMENT)	Sustainable agricultural land management offset accounting methodology for increased rotations, displacing fossil-fuel-based inputs, planting trees and establishing grassland. To be used in small-scale farming regions of the world where local biomass is an important energy source for cooking and heating.	Crop Management, Land Use Management, Residue/ Waste Management	Quantification Protocol	CO2, N2O, CH4, Soil C, C Sequestration
VCS – MSU – EPRI N2O (UNDERGOING ASSESSMENT)	Nitrogen emission reduction quantification protocol through increased fertilizer nitrogen use efficiency. Intended for cropping systems using large anthropogenic inputs of nitrogen fertilizer in the United States, with increased scientific rigour and applicability to corn row-cropping systems in the North Central Region of the continental USA.	Nitrogen Management	Quantification Protocol	N2O only. CH4 and CO2 considered de minimis
Vergé et al. 2008 Canadian Beef	LCA to assess Canadian beef production, including GHG emissions from upstream fertilizer and pesticide manufacturing, as well as on-farm crop and pasture management, animal feeding approaches, manure handling and storage, meat production and feedlot energy use management to farm-gate production.	Crop Management, Livestock Management, Farm Energy Management	LCA	N2O, CH4, CO2

Tool	Description	Agricultural Activity	Tool Type	GHG Category
Vergé et al. 2009 Canadian Pork	LCA to assess GHG emissions from Canadian pork production. Analysis includes upstream manufacturing of pesticides and fertilizers as well as on-farm cropping, animal feeding, manure handling and storage strategies and meat production to the farm gate.	Crop Management; Livestock Management	LCA	N2O, CH4, CO2
Williams, et al. 2006 UK horticulture and agriculture commodities	Attributional LCA to assess a large number of ag products: wheat, canola, potatoes, tomatoes, beef, pork, chicken, sheep, eggs and milk in the UK. Emissions are quantified from upstream chemical production, on-farm crop, feedstock and livestock management, and on farm energy use and production activities to farm gate.	Crop Management, Livestock Management, Farm Energy Management	Attributional LCA approach, allocating burden to economic output of the byproducts.	N2O, CH4, CO2 from upstream and on-farm activities to farm gate.

4.0 Benchmarking of Quantification Tools

The substantive portion of the analysis in this phase of the M-AGG initiative is the benchmarking of the quantification approaches for each of the quantification tools. This is not meant to evaluate each of the tools relative to each other or to provide some rating of their rigour. Conversely, the benchmarking progress is designed to highlight the breadth of quantification work that has been completed and to point the reader to other quantification sources within the agricultural sector.

To that end, the following sections establish the core pillars underlying the analysis and the results of the benchmarking process.

4.1 Pillars for Quantification Tool Benchmarking

Three key pillars were established to support the benchmarking process. Each of these is outlined in the following sections along with an explanation of the sub-set criteria used.

4.1.1 Scope and Framework

The first pillar of analysis focused on the macro-level characteristics of the quantification tools as a means of capturing the high-level descriptors for the quantification tool. These criteria are important as they provide a foundation for understanding the overall scope and framework for each quantification tool, and for making any comparisons among tools. Table 4.1 outlines the sub-set of criteria used for this portion of the analysis.

Table 4.1: Scope and Framework Criteria

Criteria	Description
Purpose	This criterion focuses on the stated purpose of the Tool. This may include planning, a decision support, inventory quantification, offset accounting, and LCA accounting / carbon foot printing.
Sector	This criterion addresses the agricultural sectors and subsectors (as per Table 3.2) that are applicable. This section may provide more detail.
Scope	This criterion speaks to the coverage of the tool relative to the range of greenhouse gases, over a time period, geographical reach and specific activities covered in the tool.
Approach	This criterion touches on the overall quantification approach – model, formula, empirical data, direct measurement, best practice guidance, and/or industry standard.

4.1.2 Scientific Approach

The scientific approach underlying each of the tools was reviewed. This review did not extend to a validity of the science, preferring to focus on the overall approach and its validation within/by the academic community. This analysis was thought to be more constructive given the evolving nature of the science, the potential for disparate views on approaches and a general respect for keeping scientific evaluation within the realm of qualified practitioners and researchers. Table 4.2 outlines the sub-set of criteria used for this portion of the analysis.

Table 4.2: Scientific Approach Criteria

Criteria	Description
Approach	Outline of the overall quantification approach(s) employed in the tool including description of the underlying science (applied research, field demonstration, pilot projects; theoretical model)
Basis	Supporting evidence for the quantification approach such as through published, readily available, peer-reviewed sources. Summary of the degree of vetting and/or, government acceptance in inventory, offset quantification or other capacity.
Validation	Description of the processes and individuals involved in the review and validation of the scientific approach employed in the tool.
Adaptability	Review of what would be required to adapt the protocol outside its current scope or to reach meaningful scale, as applicable.

4.1.3 Development Process

The development process behind each of the tools was also reviewed. This analysis was intended to uncover the basic information regarding tool development and practical acceptance, and not to dig deeply into policy applications. The review focused on the overall tool information available, seeking out indications of technical development, stakeholder involvement and vetting, with a further assessment of government or program acceptance, outlined below in Table 4.3.

Table 4.3: Development Process Criteria

Criteria	Description
Overall Tool Approach	Examination of the technical aspects of tool development, including who was involved, what steps were taken, how comprehensive and how accessible the technical details are. Also includes the transparency of expert review regarding who and how many people reviewed it, what credentials the reviewers had, and overall reviewer statements.
Stakeholder Input/ Review	Outline of how broadly the tool has been exposed, whether taken to a broader stakeholder community, and what sort of feedback resulted from stakeholder testing.
Independence Review/ Vetting	Indication of whether the tool has been tested by an external third party. (e.g. VCS double-validation)
Government or Program Authority	Description of whether the tool has been accepted by a government or emissions reduction program.

4.2 Quantification Tool Assessment Information Sheets:

For greater ease of understanding, the tools have been divided into three analytical tiers reflecting the three above-listed pillars for benchmarking. The first analysis assesses the tools according to their scope and framework criteria; this section is further divided by agricultural activity for ease of understanding. The second analysis assesses the tools according to their underlying scientific approaches. Finally, the third analysis assesses the tools according to the development process criteria. These tool assessment information sheets may be found in Appendix B with titular subheadings for each of the three pillars.

4.2.1 Scope and Framework Criteria Benchmark Matrices

The first subheading was created to assess each quantification tool based on the scope and framework criteria described above in section 4.1.1 and Table 4.1. The assessments were divided into the seven agricultural activity categories, with only relevant tools and activities assessed for each of the following: Soil Management, Crop Management, Nitrogen Management, Land Use Management, Livestock Management, Residue and Waste Management, and Farm Energy Management. This division allowed for agricultural-activity-specific details to be highlighted in the information sheets.

4.2.2 Scientific Approach Criteria

The second information sheet subheading was created to assess each quantification tool based on its underlying scientific approach. As discussed in section 4.1.2, the scientific approach of each tool determines how material is quantified, as well as how the tool has been validated and

verified within the scientific community. Approach, Basis, Validation and Adaptability are all addressed for each tool. These details may be found in the information sheets in Appendix B.

4.2.3 Development Process Criteria

The final information sheet subheading was created to assess each quantification tool based on the development process it has undergone. As identified in section 4.1.3, this development process analysis identifies how the tool has been reviewed and accepted by governmental and regulatory bodies. Development Process Criteria for each tool are presented in Appendix B.

4.3 Suitability as Carbon Market Access Mechanism

In order to progress the analysis, each of the quantification tools will be reviewed to establish its suitability as a carbon market access mechanism in its current form. This process will serve to filter the protocols suitable for analysis in Phase II of the M-AGG work. It will also provide limited guidance as to how the remaining tools could potentially be adapted as carbon market access mechanisms. For more information on this subject, please refer to the Agriculture Sector Greenhouse Gas Quantification Protocol Benchmarking Phase Two Report.

4.3.1 Carbon Market Access Mechanism Filter Criteria

Although not exhaustive, there are a limited number of criteria that can be applied to filter which quantification tools currently meet the basic requirements for a GHG offset quantification protocol. These criteria are qualitative and designed to provide no false-negative responses (i.e. not exclude any quantification tools that could be protocols). An overview of the criteria is included in Table 4.4.

Table 4.4: Carbon Market Access Mechanism Filter Criteria

Criteria	Description
Project Condition Definition	Does the quantification tool assign project types/activities and their configurations within the scope of applying the tool?
Baseline Scenario Selection	Are applicable baseline scenarios defined in a way that provides functional equivalence to the assigned project condition? Does the baseline selection process follow a disciplined approach, which is completely transparent and fully justified?
Defined Scope and Boundary of Analysis	Is the quantification tool assessed in such a way to ensure that an analysis of (an appropriate scope of) relevant sources of emissions and sinks is included under both the baseline and project? Does the scope and boundary analysis follow a disciplined approach, which is completely transparent and fully justified?
Quantification Methodology	Does the tool include detailed equations or similar guidance and uncertainty estimates in its calculation of GHG emissions under both project and baseline conditions?
Measurement and Monitoring Guidance	Does the quantification protocol provide specific guidance to project developers for measuring and monitoring the required parameters?
Offset Accounting Process	Is the calculation of project net GHG benefit appropriate to the protocol?
Offset Program Overlay	Are overlying offset program requirements (e.g. additionality, permanence) addressed within the determination of project net GHG benefits?

4.3.2 Evaluation

Each of the quantification tools were reviewed relative to the criteria outlined in Section 4.3.1 (Table 4.4) to filter for their suitability for further analysis in Phase II of the project as carbon market access mechanisms. The results of this review are not meant to serve as a criticism of any of the quantification tools discussed in this report, and should not be interpreted to question the validity and usefulness of these quantification tools. Many of these tools were not intended to be carbon market access mechanisms, and thus would not be expected to pass through this filter.

The results of this analysis and filtering process are presented in Table 4.5

Table 4.5: Quantification Tool Assessment based on Carbon Market Access Mechanism Filter Criteria.

Quantification Tool/ Protocol	Carbon Market Access Mechanism Filter Criteria						
	Project Condition Definition	Baseline Scenario Selection	Defined Scope and Boundary of Analysis	Quantification Methodology	Measurement and Monitoring Guidance	Offset Accounting Process	Offset Program Overlay
	Does the quantification tool assign project types/activities and their configurations within the scope of applying the tool?	Are applicable baseline scenarios defined in a way that provides functional equivalence to the assigned project condition?	Is the quantification tool assessed in such a way to ensure that an analysis of relevant sources of emissions and sinks is included under both the baseline and project?	Does the tool include detailed equations or similar guidance and uncertainty estimates in its calculation of GHG emissions under both project and baseline conditions?	Does the quantification protocol provide specific guidance to project developers for measuring and monitoring the required parameters?	Is the calculation of project net GHG benefit appropriate to the protocol?	Are the overlying offset program requirements (e.g. additionality, permanence) addressed within the determination of project and GHG benefits?
ACR Fertilizer Management	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ACR Forest Carbon	Yes	Yes	Yes	Yes	Yes	Yes	Yes
ACR Livestock Manure Management	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AOS Beef Feeding (Edible Oils)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AOS Beef Feeding (Reducing Days-on-Feed)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AOS Beef Lifecycle	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AOS Biogas	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AOS Dairy Cattle	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AOS Energy Efficiency	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AOS NERP	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AOS Pork	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Quantification Tool/ Protocol	Carbon Market Access Mechanism Filter Criteria						
	Project Condition Definition	Baseline Scenario Selection	Defined Scope and Boundary of Analysis	Quantification Methodology	Measurement and Monitoring Guidance	Offset Accounting Process	Offset Program Overlay
	Does the quantification tool assign project types/activities and their configurations within the scope of applying the tool?	Are applicable baseline scenarios defined in a way that provides functional equivalence to the assigned project condition?	Is the quantification tool assessed in such a way to ensure that an analysis of relevant sources of emissions and sinks is included under both the baseline and project?	Does the tool include detailed equations or similar guidance and uncertainty estimates in its calculation of GHG emissions under both project and baseline conditions?	Does the quantification protocol provide specific guidance to project developers for measuring and monitoring the required parameters?	Is the calculation of project net GHG benefit appropriate to the protocol?	Are the overlying offset program requirements (e.g. additionality, permanence) addressed within the determination of project and GHG benefits?
AOS Tillage	Yes	Yes	Yes	Yes	Yes	Yes	Yes
APEX - Agricultural Policy Environmental eXtender	Yes	No	No	No	No	No	No
Australian Farm GAS	Yes	No	No	No	No	No	No
Beauchemin et al. 2010 Western Canadian Beef	Yes	No	No	No	No	No	No
Biswas et al 2008 Australian Wheat	Yes	No	No	No	No	No	No
CAR - Forest Project Protocol	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CAR - Livestock Project Protocol	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Carbon Trust Carbon Label	Yes	No	No	No	No	No	No
CASA Express or CASA CQUEST	Yes	No	No	No	No	No	No

Quantification Tool/ Protocol	Carbon Market Access Mechanism Filter Criteria						
	Project Condition Definition	Baseline Scenario Selection	Defined Scope and Boundary of Analysis	Quantification Methodology	Measurement and Monitoring Guidance	Offset Accounting Process	Offset Program Overlay
	Does the quantification tool assign project types/activities and their configurations within the scope of applying the tool?	Are applicable baseline scenarios defined in a way that provides functional equivalence to the assigned project condition?	Is the quantification tool assessed in such a way to ensure that an analysis of relevant sources of emissions and sinks is included under both the baseline and project?	Does the tool include detailed equations or similar guidance and uncertainty estimates in its calculation of GHG emissions under both project and baseline conditions?	Does the quantification protocol provide specific guidance to project developers for measuring and monitoring the required parameters?	Is the calculation of project net GHG benefit appropriate to the protocol?	Are the overlying offset program requirements (e.g. additionality, permanence) addressed within the determination of project and GHG benefits?
CCX - Agricultural Best Management Practices	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CCX - Agricultural Methane	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CCX - Forestry Carbon Sequestration	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CCX - Sustainably Managed Rangeland	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CDM -- ACM0010 Manure management systems	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CDM (small-scale) -- III.A. Nitrogen Fertilizer Offset	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CLA CALM Calculator	Yes	No	No	No	No	No	No
COMET-VR/ -FARM	Yes	No	No	No	No	No	No
Cool Farm Tool	Yes	No	No	No	No	No	No
DAYCENT/ CENTURY	Yes	No	No	No	No	No	No

Quantification Tool/ Protocol	Carbon Market Access Mechanism Filter Criteria						
	Project Condition Definition	Baseline Scenario Selection	Defined Scope and Boundary of Analysis	Quantification Methodology	Measurement and Monitoring Guidance	Offset Accounting Process	Offset Program Overlay
	Does the quantification tool assign project types/activities and their configurations within the scope of applying the tool?	Are applicable baseline scenarios defined in a way that provides functional equivalence to the assigned project condition?	Is the quantification tool assessed in such a way to ensure that an analysis of relevant sources of emissions and sinks is included under both the baseline and project?	Does the tool include detailed equations or similar guidance and uncertainty estimates in its calculation of GHG emissions under both project and baseline conditions?	Does the quantification protocol provide specific guidance to project developers for measuring and monitoring the required parameters?	Is the calculation of project net GHG benefit appropriate to the protocol?	Are the overlying offset program requirements (e.g. additionality, permanence) addressed within the determination of project and GHG benefits?
DMI 2007 Dairy	Yes	No	No	No	No	No	No
DNDC/ DNDC NUGGET	Yes	No	No	No	No	No	No
FAO Carbon ExACT	Yes	No	No	No	No	No	No
FAO 2010 Dairy	Yes	No	No	No	No	No	No
Field to Market Keystone Alliance	Yes	No	No	No	No	No	No
GHGS Livestock Manure Management	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Holos	Yes	No	No	No	No	No	No
Millar et al. 2010 N2O in Corn	Yes	No	No	No	No	No	No
Pelletier 2008. Broiler Poultry	Yes	No	No	No	No	No	No
Pelletier et.al., 2010 Beef LCA comparison	Yes	No	No	No	No	No	No

Quantification Tool/ Protocol	Carbon Market Access Mechanism Filter Criteria						
	Project Condition Definition	Baseline Scenario Selection	Defined Scope and Boundary of Analysis	Quantification Methodology	Measurement and Monitoring Guidance	Offset Accounting Process	Offset Program Overlay
	Does the quantification tool assign project types/activities and their configurations within the scope of applying the tool?	Are applicable baseline scenarios defined in a way that provides functional equivalence to the assigned project condition?	Is the quantification tool assessed in such a way to ensure that an analysis of relevant sources of emissions and sinks is included under both the baseline and project?	Does the tool include detailed equations or similar guidance and uncertainty estimates in its calculation of GHG emissions under both project and baseline conditions?	Does the quantification protocol provide specific guidance to project developers for measuring and monitoring the required parameters?	Is the calculation of project net GHG benefit appropriate to the protocol?	Are the overlying offset program requirements (e.g. additionality, permanence) addressed within the determination of project and GHG benefits?
Peters et al 2010 Red Meat LCA in Australia	Yes	No	No	No	No	No	No
RGGI - Manure Management	Yes	Yes	Yes	Yes	Yes	Yes	Yes
RGGI -Afforestation	Yes	Yes	Yes	Yes	Yes	Yes	Yes
RothC Soil Carbon	Yes	No	No	No	No	No	No
VCS - Afforestation/ Reforestation	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VCS ALM Grassland Management	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VCS -SALM Agricultural Land Management	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VCS MSU-EPRI N2O	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Vergé et al. 2008 Canadian Beef	Yes	No	No	No	No	No	No

Quantification Tool/ Protocol	Carbon Market Access Mechanism Filter Criteria						
	Project Condition Definition	Baseline Scenario Selection	Defined Scope and Boundary of Analysis	Quantification Methodology	Measurement and Monitoring Guidance	Offset Accounting Process	Offset Program Overlay
	Does the quantification tool assign project types/activities and their configurations within the scope of applying the tool?	Are applicable baseline scenarios defined in a way that provides functional equivalence to the assigned project condition?	Is the quantification tool assessed in such a way to ensure that an analysis of relevant sources of emissions and sinks is included under both the baseline and project?	Does the tool include detailed equations or similar guidance and uncertainty estimates in its calculation of GHG emissions under both project and baseline conditions?	Does the quantification protocol provide specific guidance to project developers for measuring and monitoring the required parameters?	Is the calculation of project net GHG benefit appropriate to the protocol?	Are the overlying offset program requirements (e.g. additionality, permanence) addressed within the determination of project and GHG benefits?
Vergé et al. 2009 Canadian Pork	Yes	No	No	No	No	No	No
Williams, et al. 2006 UK horticulture and agriculture commodities	Yes	No	No	No	No	No	No

4.4 Summary and Next Steps

From the preceding table (Table 4.5), a clear distinction emerges as to which of the quantification tools are suitable for further consideration as market access mechanisms as many of the tools achieved a positive response to all of the criteria in Table 4.5. As such, these tools, as summarized in Table 4.6, and will be examined in greater detail in Phase II of the M-AGG initiative.

Table 4.6: Quantification Tools Suitable for Phase II Analysis

Quantification Tools	
ACR Fertilizer Management	CCX -- Agricultural Best Management Practices
ACR Forest Carbon	CCX -- Agricultural Methane
ACR Livestock Manure Management	CCX -- Forestry Carbon Sequestration
AOS Beef Feeding (Edible Oils)	CCX -- Sustainably Managed Rangeland
AOS Beef Feeding (Reducing Days-on-Feed)	CDM -- ACM0010 Manure Management Systems
AOS Beef Lifecycle	CDM (small-scale) -- III.A. Nitrogen Fertilizer Offset
AOS Biogas	GHGS Livestock Manure Management
AOS Dairy Cattle	RGGI -- Manure Management
AOS Energy Efficiency	RGGI --Afforestation
AOS NERP	VCS – ALM Grassland Management
AOS Pork	VCS -SALM Agricultural Land Management
AOS Tillage	VCS – Afforestation/ Reforestation
CAR -Forest Project Protocol	VCS MSU-EPRI N2O
CAR -- Livestock Project Protocol	

Appendix A. Quantification Tools and Reference Materials

Tool	Tool link/ Website/ Journal Citation
ACR Fertilizer Management; Methodology for Emission Reductions through Changes in Fertilizer Management	www.americancarbonregistry.org/carbon-accounting/emissions-reductions-through-changes-in-fertilizer-management (CURRENTLY UNDER REVIEW FOR APPROVAL)
ACR Forest Carbon Project Standard	www.americancarbonregistry.org/carbon-accounting/forest-carbon-project-standard-v2.0
ACR Livestock Manure Management Project Standard	www.americancarbonregistry.org/carbon-accounting/livestock-manure-management-project-standard-v1.0
AOS Beef Feeding (Edible Oils) Quantification Protocol	http://environment.gov.ab.ca/info/library/7970.pdf
AOS Beef Feeding (Reducing Days-on-Feed) Quantification Protocol	http://carbonoffsetsolutions.climatechangecentral.com/files/microsites/OffsetProtocols/ApprovedAlbertaProtocols/Beef_Days_on_Feed_Protocol_v1_May_08%20Update%20Aug%2008.pdf
AOS Beef Lifecycle Quantification Protocol	http://environment.gov.ab.ca/info/library/7916.pdf
AOS Biogas Quantification Protocol	http://environment.gov.ab.ca/info/library/7917.pdf
AOS Dairy Cattle Emission Reduction Quantification Protocol	http://environment.gov.ab.ca/info/library/8255.pdf
AOS Energy Efficiency Quantification Protocol	http://environment.gov.ab.ca/info/library/7909.pdf
AOS NERP Nitrous oxide Emission Reduction Protocol Quantification Protocol	(CURRENTLY UNDER REVIEW FOR APPROVAL) http://carbonoffsetsolutions.climatechangecentral.com/files/microsites/OffsetProtocols/ProtocolReviewProcess/5thCycleProtocolDevelopment/NERP_FINAL_Draft_Protocol_postreview.pdf
AOS Pork Quantification Protocol	http://environment.gov.ab.ca/info/library/7913.pdf
AOS Tillage Quantification Protocol	http://environment.gov.ab.ca/info/library/7918.pdf
APEX - Agricultural Policy Environmental eXtender (adapted from EPIC - Erosion Productivity Impact Calculator - and SWAT - Soil and Water Assessment Tool)	http://www.brc.tamus.edu/apex.aspx

Tool	Tool link/ Website/ Journal Citation
Australian Farm Institute Farm GAS	http://farmgas.farminstitute.org.au
Beauchemin et al. 2010. LCA of GHGs from beef production in Western Canada: a case study.	Beauchemin, K.A., Janzen H.H., Little, S.M., McAllister, T.A., and McGinn, S.M. 2010. Lifecycle assessment of greenhouse gas emissions from beef production in western Canada: A case study. Agricultural Systems. IN PRESS doi:10.1016/j.agsy.2010.03.008
Biswas et al 2008; Global warming potential of wheat production in Western Australia: A life cycle assessment.	Biswas, W.K., Barton, L., Carter, D. 2008. Global warming potential of wheat production in Western Australia: a lifecycle assessment. Water and Environment Journal. 22 (3): 206-216 doi:10.1111/j.1747-6593.2008.00217.x
CAR - Forest Project Protocol	http://www.climateactionreserve.org/wp-content/uploads/2009/03/Forest-Project-Protocol-Version-3.1.pdf
CAR -- Livestock Project Protocol Capturing and Destroying Methane from Manure Management Systems	http://www.climateregistry.org/resources/docs/protocols/project/livestock/CCARLivestockProjectReportingProtocol2.1.pdf
Carbon Trust; Carbon Label Company Crop Calculator	CARBON TRUST Working with: www.defra.gov.uk; www.ecoinvent.org; the calculator can be found on Carbon Trust's website: www.carbontrust.co.uk under "Cut Carbon & Reduce Costs"
CASA Express (ArcGIS Toolkit version) **or CASA CQUEST** (internet-accessible version of software)	CASA EXPRESS CQUEST http://geo.arc.nasa.gov/sge/casa/index.html NASA-CASA Express model. (National Aeronautics and Space Administration - Carnegie Ames Stanford Approach) CQUEST online tool (slightly more limited in scope and customizability): http://sgeaims.arc.nasa.gov/website/cquest/viewer.htm
CCX - Agricultural Best Management Practices -Continuous Conservation Tillage and Conversion to Grassland Soil Carbon Sequestration Offset Project Protocol	http://www.chicagoclimatex.com/docs/offsets/CCX_Agricultural_Methane_Final.pdf
CCX - Agricultural Methane Collection and Combustion Offset Project Protocol	http://www.chicagoclimatex.com/docs/offsets/CCX_Conservation_Tillage_and_Grassland_Conversion_Protocol_Final.pdf
CCX - Forestry Carbon Sequestration Project Protocol	http://www.chicagoclimatex.com/docs/offsets/CCX_Forestry_Sequestration_Protocol_Final.pdf
CCX - Sustainably Managed Rangeland Soil Carbon Sequestration Offset Project Protocol	http://www.chicagoclimatex.com/docs/offsets/CCX_Sustainably_Managed_Rangeland_Soil_Carbon_Sequestration_Final.pdf

Tool	Tool link/ Website/ Journal Citation
CDM -- ACM0010, Consolidated methodology for GHG emission reductions from manure management systems --- Version 5	http://cdm.unfccc.int/methodologies/sccmethodologies/approved.html
CDM (small-scale) - III.A. Offsetting of synthetic nitrogen fertilizers by inoculant application in legumes-grass rotations on acidic soils on existing cropland	http://cdm.unfccc.int/UserManagement/FileStorage/BZG8LM2WO95IDQJCF634VUYTPNEKRX
CLA CALM – Carbon Accounting for Land Managers	http://www.calm.cla.org.uk/
COMET-VR/ -FARM	www.cometvr.colostate.edu
Cool Farm Tool	Some information here under "Climate Assessment Launch" : http://www.sustainablefoodlab.org/projects/climate
DAYCENT/ CENTURY	CENTURY/ DAYCENT no website found for the model. Information may be found here: http://www.nrel.colostate.edu/projects/daycent/index.html
DMI 2007; Carbon Footprint of US Dairy Sector	none listed
DNDC/ DNDC NUGGET	DNDC NUGGET is an online version of the DNDC tool: http://nugget.sr.unh.edu. More information and model materials can be found on this website: http://www.dndc.sr.unh.edu/
FAO 2010 Dairy GHG emissions from the dairy sector: A lifecycle Assessment.	http://www1.eere.energy.gov/biomass/pdfs/37500.pdf
FAO EX-ACT: EX-ante Appraisal Carbon Balance Tool	www.fao.org/tc/tcs/exact/en/
Field to Market: The Keystone Alliance for Sustainable Agriculture	http://keystone.org/files/file/SPP/environment/field-to-market/Field-to-Market_Environmental-Indicator_First_Report_With_Appendices_01122009.pdf
GHGS -- Methodology for Agricultural Livestock Manure Management System Methane Capture and Destruction Projects	http://www.aes.com/pub-sites/sites/GHGS/content/live/020139c6f734011c6db82862007bdd/1033/GHGS%20AgWaste%20Methodology%20Version%201.0.pdf
HOLOS	HOLOS http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1226606460726&lang=eng

Tool	Tool link/ Website/ Journal Citation
Millar et al. 2010 N2O mitigation in corn	Millar N., Robertson, G.P., Grace, P.R., Gehl, R.J., and Hoben, J.P. 2010. Nitrogen fertilizer management for nitrous oxide (N2O) mitigation in intensive corn (Maize) production: an emissions reduction protocol for US Midwest agriculture. Mitigation and Adaptation Strategies for Global Change. 15(2): 185 - 204. Article should be open access at: http://www.springerlink.com/content/l2n3gh1370p5h656/?p=fad710f4cecf44ddaff5b67e6da18aa9&pi=4
Pelletier 2008. Broiler Poultry	Pelletier, N. 2008. Environmental performance in the US broiler poultry sector: Lifecycle energy use and greenhouse gas, ozone depleting, acidifying, and eutrophying emissions. Agricultural Systems. 98 (2): 67-73 doi:10.1016/j.agsy.2008.03.007
Pelletier et.al. 2010. Beef LCA comparison	Pelletier, N., Pirog, R., Rasmussen, R. 2010. Comparative lifecycle environmental impacts of three beef production strategies in the upper Midwestern United States. Agricultural Systems. IN PRESS. Doi:10.1016/j.agsy.2010.03.009
Peters et al 2010. Red Meat LCA in Australia	Peters, G. M., Rowley, H.V., Wiedemann, S., Tucker, R., Short, M.D., Schulz, M. 2010. Red meat production in Australia: Lifecycle assessment and comparison with overseas studies. Environmental Science and Technology. 44 (4): 1327 - 1332 doi:10.1021/es901121e
RGGI -- Manure Management	Pages 121 to 128 in Model Rule, http://www.rggi.org/docs/Model%20Rule%20Revised%2012.31.08.pdf
RGGI --Afforestation	Pages 106 to 112 in Model Rule, http://www.rggi.org/docs/Model%20Rule%20Revised%2012.31.08.pdf
RothC Soil Carbon	http://www.rothamsted.bbsrc.ac.uk/aen/carbon/rothc.htm
VCS ALM Grassland Management - Adoption of Sustainable Grassland Management through Adjustment of Fire and Grazing	http://v-c-s.org/methodology_alma.html
VCS -- Afforestation/ Reforestation of Agricultural Lands Version 2 -- July 2009	http://www.v-c-s.org/docs/AR%20of%20agricultural%20land%20V2%20submitted,%20reconverted.pdf
VCS -SALM - Adoption of sustainable agricultural land management (SALM).	http://www.v-c-s.org/docs/SALM%20Methodolgy%20Final_%20validation.pdf
VCS MSU-EPRI N2O – Quantifying N2O Emissions Reductions in US Agricultural Crops through N Fertilizer Rate Reduction	http://www.v-c-s.org/docs/VCS%20N2O%20Reduction%20Methodology%20and%20Annexes%20v1.pdf

Tool	Tool link/ Website/ Journal Citation
Vergé et al. 2008 Canadian Beef	Vergé, X.P.C., Dyer, J.A., Desjardins, R.L., Worth, D.L., 2008. Greenhouse gas emissions from the Canadian beef industry. Agricultural Systems. 98 (2): 126 - 134 doi:10.1016/j.agsy.2008.05.003
Vergé et al. 2009 Canadian Pork	Vergé, X.P.C., Dyer, J.A., Desjardins, R.L., Worth, D. 2009. Greenhouse gas emissions from the Canadian pork industry. Livestock Science. 121 (1): 92 - 101 doi:10.1016/j.livsci.2008.05.022
Williams et al. 2006 UK horticulture and agriculture commodities	Williams, A.G., Audsley, E. and Sandars, D.L. 2006. Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Main Report. Defra Research Project IS0205. Bedford: Cranfield University and Defra. Document is difficult to find on the internet due to organisational changes to the Cranfield University and DEFRA websites.

Appendix B. Glossary of Terms and Acronyms

GHGs Greenhouse Gas(es)

C	carbon
CH4	methane
CO2	carbon dioxide
CO2e	carbon dioxide equivalent (for calculating atmospheric temperature change effect)
N / N2	nitrogen/ nitrogen gas
N2O	nitrous oxide
NOx	generic category of nitrogen compounds known to be GHGs
NO3	nitrate
ODS	Ozone Depleting Substances

Tools and Concepts

ACM	Approved Consolidated Methodology (from the CDM)
AFOLU	Agriculture, Forestry and Other Land Uses
APEX	Agricultural Policy Environmental eXtender (adapted from EPIC and SWAT)
AR	Afforestation/ Reforestation
AWMS	Animal Waste Management System
Best Practice Guidance	a technique, method, process, activity, incentive or reward that is believed to be more effective at delivering outcome than any other technique, method etc. when applied to a particular condition or circumstance. OR the most efficient and effective means of accomplishing a task, based on repeatable procedures proven over time and a large number of independent replicates.
CASA	Carnegie Ames Stanford Approach (NASA-CASA Project)
CQuEST	Carbon Query and Evaluation Support Tools

De minimis	so small or minimal in difference that it does not matter or is not taken into consideration
DNDC	DeNitrification, DeComposition calculator
EONR	(From Millar et al.) Economically Optimum Nitrogen application Rate: balance of cost vs production gains of fertilizer application and plant growth response
EPIC	Erosion Productivity Impact Calculator
ERG MANURE	Eastern Research Group Manure and Nutrient Reduction Estimator tool
ERT	Emission Reduction Ton(ne): tradable carbon offset unit of the ACR
Ex-ante	Based on anticipated changes
Ex-post	Based on analysis of past performance
FPCM	Fat and Protein Corrected Milk
GPG 2000	Good Practice Guidance report on Uncertainty Management in National Greenhouse Gas Inventories
GPG LULUCF	Good Practice Guidance for Land Use, Land Use Change and Forestry
IEUA MRV	Inland Empire Utility Agency Monitoring, Reporting and Verification Protocol
IFM	Improved Forest Management
ILUC	Indirect Land Use Change
ISO 14040	ISO 14000 series addresses different aspects of environmental management through specific standards. The ISO 14040 standard addresses Lifecycle Assessments.
Kyoto Annex 1	Kyoto Protocol list of industrialized countries (members of the OECD (Organization for Economic Co-operation and Development) in 1992) and economies in transition including the Russian Federation, the Baltic States and several Central and Eastern European States (list of Annex 1: http://unfccc.int/parties_and_observers/parties/annex_i/items/2774.php)
Kyoto Non-Annex 1	Kyoto Protocol list of mostly developing countries including those especially vulnerable to the adverse effects of climate change, and those more vulnerable to the economic effects of climate change response measures. (list of non-Annex 1: http://unfccc.int/parties_and_observers/parties/non_annex_i/items/2833.php)
LCA	Lifecycle Analysis
LCI	Lifecycle Inventory
MLRA	Major Land Resource Area
MRTN	(From Millar et al.) Maximum Return To Nitrogen application: reflecting growth return response to fertilizer application
NRCS SSURGO	National Resources Conservation Service Soil Survey Geographic database
PNRR	(From Millar et al.) Economically Profitable Nitrogen application Rate Range: most profitable balance of the economic costs of fertilizer application and the responding crop production
REDD	Reducing Emissions from Deforestation and Degradation
SALM	Sustainable Agriculture Land Management
SSR	Sources, Sinks and Reservoirs of GHGs
SWAT	Soil and Water Assessment Tool
(Tile) Drainage	Land improvement practices to remove water from the soil subsurface to drain excess water from crop rooting zone through the installation of corrugated plastic tubing, clay and concrete drainage tiles. Overall goals aim to increase efficiency and productivity on drained lands.
VCU	Voluntary Carbon Unit (tradable carbon credit from the VCS)

Supporting or Associated Agencies

AAFC	Agriculture and Agri-Food Canada
ACR	American Carbon Registry
AOS	Alberta Offset System
BSI	British Standards Institution
CAR	Climate Action Reserve
CCAP	Climate Change Adaptation Program
CCX	Chicago Climate Exchange
CDM	Clean Development Mechanism
CGIAR	Consultative Group on International Agricultural Research
DEFRA	Department of Environment, Food and Rural Affairs of the UK national government
DMI	Dairy Management Inc.
DOE	Department of Energy of the United States' Energy Information Administration. DOE 1605(b) refers to the Voluntary Reporting of Greenhouse Gases Program.
FAO	Food and Agriculture Organization of the United Nations
FIL - IDF	Fédération International de Laiterie - International Dairy Federation
FINRA	Financial Industry Regulatory Authority
GCI	Global Cities Institute
GHGS	(General Electric) GE AES Greenhouse Gas Services, LLC
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JI	Joint Implementation (as part of the UNFCCC)
MAFF	Ministry of Agriculture, Forestry, and Fisheries of the UK national government (department preceding DEFRA)
MLC	Meat and Livestock Commission of the UK
NASS	National Agriculture Statistics Service of the USDA
NIR	National Inventory Report (e.g. for the UK, Canada etc.)
NGOs	Non-Governmental Organisations
NREL	Natural Resources Ecology Lab at Colorado State University, Ft. Collins, CO.
PAS 2050	Publically Available Specification independent standard for assessing product lifecycle GHG emissions From the BSI.
PASA	Pennsylvania Association for Sustainable Agriculture
RGGI	Regional Greenhouse Gas Initiative
RMIT	Royal Melbourne Institute of Technology
UNFCCC	United Nations Framework Convention on Climate Change
USDA	United States Department of Agriculture
US EPA	United States Environmental Protection Agency
VCS	Voluntary Carbon Standard
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute
WRI	Greenhouse Gas Protocol – A corporate Accounting and Reporting Standard (http://www.ghgprotocol.org/files/ghg-protocol-revised.pdf)