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
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. N2O, CH4, CO2, other gases and nutrients including P and N.	Crop Management, Livestock Management
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 (N2O, CH4, CO2). LCA suggests changes to Livestock Management approaches.	Crop Management, Livestock Management, Farm Energy Management
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; N20, CH4 an CO2.	Crop Management, Livestock Management, Farm Energy Management
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. N2O, CH4, CO2 accounted for.	Crop Management; Livestock Management
Williams, et al. 2006 UK commodiites	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 (N20, CO2 and CH4) to farm gate.	Crop Management, Livestock Management, Farm Energy Management
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; covers CO2 and N20 gases.	Crop Management, Nitrogen Management, Farm Energy Management
On-Farm Calculators/Decision Support Tools		
Carbon Trust carbon Label	Carbon footprint calculator intended for crop production and thus to include agriculture in a full carbon footprint calculation. CO2 emissions only. Soil carbon is excluded from accounting	Management of Soil, Crop Nitrogen, Land Use and Farm Energy
COMET-VR/ (and soon to be released COMET-FARM	The Voluntary Reporting of greenhouse gases - Carbon Management Evaluation Tool (COMET-VR) 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. Soil carbon is modeled currently, N20 estimation is in the works (COMET-FARM)	Management of Soil, Crop Nitrogen, Land Use, and Farm Energy
Cool Farm Tool	Calculator to estimate the current carbon footprint of each farming system being evaluated. Based on linear models of IPCC Tier 1 and Tier 2 equations. Calculates N2O, CH4, CO2 at coarse country levels.	Management of Soil, Crop Nitrogen, Land Use, Livestock and Farm Energy
DNDC NUGGET	Calculator application of DNDC model. (see description of DNDC above). N2O, NOx, N2, CH4, and CO2. From cropping systems (including rice CH4), grazing systems and manure application/ management. Nitrate leaching loss (NO3). Soil carbon sequestration, crop development and biomass yields	Management of Soil, Crop Nitrogen, Land Use, and Farm Energy
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
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. N2O, CH4, CO2 accounted for.	Management of Soil, Crop Nitrogen, Land Use, Livestock and Farm Energy

Summary Table: Quantification Tools Reviewed in M-AGG Phase 1 Report

Name	Description	Agricultural Activity
Quantification Protocols		
ACR Livestock Manure Management	Anaerobic digester offset accounting protocol for dairy cattle and swine manure management only. The protocol includes assessments of CH4, CO2, and N2O emission reductions through biogas control systems, combustion and waste management & disposal. It has been developed for implementation in the USA with further adaptation to developing nations through the combined use of ACR and CDM methodologies. CURRENTLY UNDER REVIEW FOR APPROVAL	Livestock Management
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
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
AOS Beef Feeding (Edible Oils)	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
AOS Beef Feeding (Reducing Days-on-Feed)	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
AOS Beef Lifecycle	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
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
AOS Dairy Cattle	Alberta dairy farm offset accounting protocol to increase annual per-cow milk production, reducing emissions (CO2, CH4 and N20) 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
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
AOS NERP Nitrous Oxide Emission Reduction Protocol	Nitrogen emission quantification protocol based on the implementation of comprehensive nitrogen management plans for optimum crop nitrogen uptake following a 4-R approach for crop system nitrogen management. The protocol follows IPNI beneficial management practices. CURRENTLY UNDER REVIEW FOR APPROVAL	Nitrogen Management

AOS Pork	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
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
CAR - Forest Project Protocol	Offset accounting protocol for reforestation/afforestation projects on lands with less than 10% tree canopy for at least 10 years prior. Activities can occur on public or private lands. CO2, Soil C-sequestration, Biomass accounted for.	Crop Management
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; methane emissions accounted for.	Livestock Management, Residue/ Waste Management
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. CO2 only, Soil C-sequestration	Soil Management and Crop Management
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; methane emissions only.	Livestock Management, Residue/ Waste Management
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%. CO2, C Sequestration, biomass; excludes N2O	Crop Management
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. CO2 only, Soil-C Sequestration	Livestock Management
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; methane emissions only.	Livestock Management
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. N2O, CO2, CH4	Crop Management
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; CH4, CO2 accounted for	Livestock Management, Residue/ Waste Management
VCS - Afforestation/ Reforestation	Afforestation offset accounting methodology (CO2 sequestration only). 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
VCS -SALM Agricultural Land Management	Sustainable agricultural land management offset accounting 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. CO2, N2O, CH4, Soil C, C Sequestration	Crop Management, Land Use Management, Residue/ Waste Management
Measurement Techniques		
CASA Express or CASA CQUEST	Process-based 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. N2O, CH4, CO2; some NH4 and NO in California.	Management of Soil, Crop Nitrogen, Land Use and Livestock Management (as it pertains to grazing)
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. N2O, CO2, CH4, as net greenhouse gas fluxes	Soil Management, Crop Management, Nitrogen Management, Land Use Management
APEX - Agricultural Policy Environmental eXtender	Process-based model assessing complete C and N cycles, soil C storage and N20 fluxes, 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).	Management of Crop Nitrogen; Land Use and Livestock
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 carbon and nitrogen fluxes	Soil Management, Crop Management
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 denitriifcation. N2O, Nox, N2, CH4, and CO2 modeled.	Soil Management; Crop Management; Nitrogen Management; Land Use Management;
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. N2O, CO2, C-sequestration	Crop Management, Nitrogen Management, Farm Energy Management
Millar et al. 2010 N2O in Corn	Quantification method outlining fertilizer over-application avoidance via crop rotation, reduced N-Fertilizer application and credit trading. N20 only.	Crop Management, Nitrogen Management
RGGI - Manure Management	Quantification method for methane emission avoidance through capture and destruction from stored livestock manure (CH4 gas only). 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
RGGI - Afforestation	Quantification method 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. Carbon sequestration only	Crop Management
Life Cycle Assessments		
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
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. N2O, CH4, CO2 accounted for.	Crop Management, Nitrogen Management, Livestock Management, Farm Energy Management
FAO 2010 Dairy	LCA to assess GHG emissions (N20, CH4 and CO2) 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