Guide to Developing a Quantification Methodology and Protocol:

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***Important Note**: This is a historical draft report that was prepared for discussion purposes only as the requirements of the greenhouse-gas offset system were not fully determined when it was prepared; this report has not been formally reviewed or approved by the Government of Canada. The report contents may have limited applicability to any greenhouse-gas offset system*

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1 Section I Project and Methodology Scope and Description

This section will demonstrate how the Project Proponent will reduce GHG emissions/removals through the project. It will provide a foundation of the project's quantification elements that will be justified in Section II.

Introduction to agricultural soil carbon sink Projects under this quantification protocol

This quantification protocol follows a template that includes very precise language. This is required to ensure that Project submissions supported by this protocol are comprehensive and meet Canadian and international standards. Quantification means that at least the major
carbon sink will be measured under this protocol. The use of this template is also meant to lower the cost to farmers of submitting a Project under this protocol.

This protocol also contains much scientific reference and discussion regarding statistical design. This discussion is required to explain to the public, how the authors of this protocol determined the proposed sampling design is the most efficient and least costly means of measuring carbon.

Throughout the document there are references to factors and coefficients. These are numbers that have been calculated by groups such the developers of GHGFarm or others under Canada's National Soil Carbon and Greenhouse Gas Accounting and Verification System, which allow Project Proponents to estimate CO_2 equivalent values for some elements of their project. These estimates can be used to project the future carbon credits and consequently revenue that might be provided by a Project without costly measurement. These kinds of numbers can also be used to convert measurements into CO_2 values, which is the required unit of measure under all protocols.

There is reference in this document to the term 'de minimis'. There are some very minor, mostly emission related elements, that by international and Canadian rules must be considered, but related to the largest affects being measured, are trivial, and not worth the cost of measuring, even if they would increase credits by some small amount. These are de minimis elements. These elements in effect increase the cost of a Project under this protocol with no significant benefit to anyone. For that reason a de minimis standard of 5% of the change in soil organic carbon is set under this protocol.

Relevance is a factor in determining what issues must be considered. For example, potential elements of the carbon credit calculation can be excluded if there is no change for those elements between the 'business as usual' practice and the change in practices proposed in the protocol.

The elements being measured under this protocol is the change in carbon content of the soil and the change in green house gas emissions that result from a change to a new soil-improving practice in a Project under this protocol.

Examples of the elements that may be considered are explained in the table below.

Assessment Element	Explanation
Measured soil organic carbon (SOC) – measured for example - spring/fall start of year 1, spring/fall of year 5	Carbon in the soil is measured at the start and after 5 years of the project to determine the change in SOC over time that resulted from a change in practice. To aid in determining project feasibility the amount of SOC that could be sequestered can be estimated using coefficients or factors outlined or referenced in the document.

Emissions from transportation of farm inputs	This element assesses the change in delivery of herbicides and fertilizers and is a very minor input that is often left out of the calculation. This element would only possibly be assessed where the farms own the trucks doing the transportation of materials. Where the farm(s) do not own the trucks transporting materials this element is excluded under this protocol due to lack of ownership and difficulty in determining accurate estimates of emissions. These emissions can be estimated using coefficients or factors outlined.
Emissions from equipment manufacture	The change quantified in this element assesses the change in machine life cycle, in other words how long particular classes of farm machinery last under different farming methods. Machinery used in zero-till farming practices lasts longer than machinery used in conventional till, and that is reflected in applied coefficients/ factors. These emissions can be estimated using coefficients or factors outlined.
Emissions from pesticide manufacture	This element assesses the change in emissions from the manufacture of pesticides to be used on the Project farm(s); may be a very minor input that is often left out of the calculation. These emissions can be estimated using coefficients or factors outlined.
Emissions from fertilizer manufacture	This element assesses the change in emissions from the manufacture of fertilizer to be used on the Project farm(s); may be a very minor input that is often left out of the calculation. These emissions can be estimated using coefficients or factors outlined.

Sequestration of CH_4 in soil from natural processes	This element assesses the change in methane in the soil but is a very small number and is not measured.
Emissions from onsite operation of farm machinery and vehicles	This element assesses the change in emissions from the operation of farm machinery and vehicles on the Project farm(s). These emissions can be estimated using coefficients or factors outlined.
Emissions from truck transportation of farm products	This element assesses the change in emissions from truck transportation of farm products where the farm owns the trucks. This element is usually a small decrease in emissions that is easy to assess from farm receipts and converted to CO_2 equivalents for inclusion in carbon credits. These emissions can be estimated using coefficients or factors outlined.
Emissions from rail transportation of product	This element is excluded under this protocol due to lack of ownership and difficulty in determining accurate estimates of emissions.
Emissions from storage of product	This element is excluded under this protocol due to lack of ownership and difficulty in determining accurate estimates of emissions.
Emissions from affect on market	This element is excluded under this protocol as most Projects under this protocol are not of a large enough scale to influence markets.

An example calculation of potential carbon credits for a proposed project is provided below:

The example farm is comprised of 512 ha (2 sections) on Dark Brown Chernozemic soils on the prairies, suitable for sampling using the methods of this protocol, and where the Project consists of a switch from conventional till to zero till. This will require some changes in equipment and in herbicide requirements. Initially, no changes are planned in fertilizer applications. The farm does not transport its own inputs or products, so has the option to eliminate these factors from the carbon credit estimate and the final calculation

Estimate example - preliminary analysis

Assessment Element: Soil Organic Carbon	Means to Estimate Change per ha per year How to advise Proponent on this choice?
Emissions from transportation of farm inputs	Delete due to no ownership.
Emissions from equipment manufacture	GHGFarm
Emissions from herbicide manufacture	Declare de minimis
Emissions from fertilizer manufacture	There will be no change in fertilizer regime therefore leave out of calculation (fails relevance test)
Sequestration of CH_4 in soil from natural processes	Declare de minimis
Emissions from onsite operation of farm machinery and vehicles	GHGFarm
Emissions from herbicide application	GHGFarm
Emissions from truck transportation of farm product	Delete due to no ownership.
Emissions from rail transportation of product	Delete due to no ownership.
Emissions from storage of product	Delete due to no ownership.
Emissions from affect on market	Delete due to no ownership.

Estimate example - preliminary calculation analysis

Assessment Element	Carbon Credit Calculations in tonnes CO_2 per year (y) (1 metric tonne (T) = 1 credit) (1TC = 3.67 TCO_2)		Element Total T/ha
Soil Organic Carbon (SOC)	Sink	Estimate adapted from Table 1.1 that approximated local conditions	
	Formula	Increase in SOC in T X 3.67 (factor to change C into CO_2 equivalents)	
	Calculation	0.5 X 3.67 =	1.835
Emissions from equipment manufacture	Reduction	GHGFarm Tables 23 and 24	0.013
	Formula	CT Machinery (gigajoules (GJ)/ha X CO_2 (kg CO_2 GJ)-ZT Machinery (gigajoules (GJ)/ha X CO_2 (kg CO_2 GJ)	
	Calculation	((0.67X70)-(0.48X70))/1000=	
Emissions from onsite operation of farm machinery and vehicles	Reduction	GHGFarm Tables 23 and 24	0.049
	Formula	CT Fuel (gigajoules (GJ)/ha X CO_2 (kg CO_2 GJ)-ZT Fuel (gigajoules (GJ)/ha X CO_2 (kg CO_2 GJ)	
	Calculation	((2.02X81)-(1.42X81))/1000=	
Emissions from herbicide application	Source	GHGFarm Tables 23 and 24	-0.013
	Formula	CT Herbicide (gigajoules (GJ)/ha X CO_2 (kg CO_2 GJ)-ZT Herbicide (gigajoules (GJ)/ha X CO_2 (kg CO_2 GJ)	
	Calculation	((0.16X43)-(0.46X43))/1000=	
Total Tonnes emissions reductions and removals per ha per year			1.884
Total Tonnes emissions reductions and removals per year on 512 ha			965
Total Tonnes emissions reductions and removals for this farm over 5 years (which equals total carbon credits)			4,825
Total cash value of credits at $15 per credit			$72,375

Ct = Conventional or Intensive, Till ZT = Zero or No-Till

1.1 Description and Scope

The description and scope should demonstrate how the project will reduce/remove GHG emissions, including the technology and services to be used. It should also include the main activities to be quantified as well as the activities that are outside the proposed project.
After registration, this information will be posted on the Canada's Greenhouse Gas Offset System website. For administrative purposes, the posted information should not exceed five pages.

This quantification protocol was prepared for the Soil Management Technical Working Group under the lead of the Department of Agriculture and Agri-Food Canada for potential inclusion in proposed national and provincial greenhouse gas (GHG) crediting systems.

This document presents a protocol for the quantification of (GHG) sources, sinks and removals attributable to agricultural soil carbon (C) sink Projects in Canada under a measurement approach. Given the potential range of conditions across the country and the variety of specific activities that may be involved in agricultural soil carbon sink Projects, this protocol serves as a generic 'recipe' for Project Proponents to follow in order to meet the measurement, monitoring and GHG quantification requirements of Canada's Offset System.

The National Offset quantification team is working to promote the development of standardized Offset System protocols and make these readily available to Offset Project Proponents. Standardized Offset System quantification protocols (OSQP) minimize risk and uncertainty for both Project developers and Offset buyers. Setting common protocol definitions and standards for quantifying GHG reductions or removals associated with agricultural soil carbon sink projects across Canada will catalyze investment in Offset System activities across the country.

As this document will form the core of a Proponent's application, the Offset System Program Authority and third party certified verifiers will also be using it as the basis for registration and subsequent verification of reductions or removals. A Proponent that uses this protocol must demonstrate that their proposed Project is within the scope of the protocol and that any procedural adjustments made to better fit the Project's circumstances are based on detailed justification.

The Project Proponent will use this protocol by reference. That is, the Project Proponent is not required to explain and justify the procedures or to reproduce the text of the OSQP in their Project application. The Program Authority will validate that the Project is within the scope of the OSQP and that any adjustments made by the Project Proponent will be allowed for in the OSQP.

Carbon credits are calculated under this protocol by the comparison of measured soil organic carbon (SOC) sequestration, and estimated emissions under a soil-improving change in practice, with the measured SOC values and estimated emissions under business as usual or baseline activities.

If the change in farming practices under the proposed Project is anticipated to result in a net removal or sequestration of carbon, then the area under the new practice is eligible for submission of an application under this protocol. The submitter is referred to as a Proponent. Once approved by the Project Authority, a Registered Project Document will be issued that outlines the obligations of each party.

To establish baseline values in a manner that will not disqualify prospective Proponents for practice changes prior to 2006 and later than 2005, baseline practices must be documented from records for 5 years prior to the change in practice. As well, the effects of baseline practices must be estimated from coefficients or models.

Soil-improving farming practices eligible for consideration as measured Projects under this protocol include transition to the following soil-improving practices:

- **reduced till, ridge and strip till**
- **zero till**
- **reduced fallow frequency and weed management (herbicides versus tillage)**
- **incorporation of nitrogen fixing plants in crop farming practices**
- **conversion from till or zero till to permanent perennial forage**

These farming practices are reasonably anticipated to result in the sequestration of carbon and a net decrease in greenhouse gas emissions from farming activities and meet Offset System definitions of defined practices.

The term required though, to demonstrate a change in SOC will be at least 5 years and may be as long as 10 years. Similarly dynamic baselines, where changes are small may not be statistically measurable during the term of the Project, or sampling costs may make the Project uneconomic. If so, dynamic baselines may be determined from SOC sequestration models.

All of a farmer’s fields in a project are evaluated in the Project, regardless of the farming practice employed on a particular field. In this way, the measurement of SOC for the Project is not influenced by a shift of practices from one field at the expense of another.

Eligible measured Projects under the Offset System agricultural protocol will be specific to particular soil types as defined under the Canada Soil Information System, where net carbon sequestration is feasible.

Two examples of Projects under the agricultural soil carbon sink protocol are located in Annex 13.

Specific soil types in several farming regions have either demonstrated no consistent sequestration of SOC as a result of the implementation of soil-improving practices, or no refereed publications could be found to support the potential for GHG reductions. Such cases will become candidates for Project under this protocol when and if measurable GHG reductions due to soil-improving practices can be identified. For soils with high initial SOC content, the number of samples required to determine additional sequestration is likely to be uneconomical. Also farming practices are continuing to evolve and new farming practices that meet soil-improving practices criteria may be developed in the future. Under these scenarios, additional farming practices may become eligible for Project consideration.
Accordingly Project Proponents must carefully select and define both practices to be applied under their Project proposal, and the area to which it will be applied.

Rates of carbon sequestration reported in the literature are listed in Table 1.1.

Table 1.1 Literature review of soil organic carbon sequestration based on various farming systems.

Reference	Location/Soil type	Tillage system	Crop rotation	SOC Sequestered (T ha^{-1} yr^{-1})
West and Post, 2002	These values were taken from within the literature and compiled by West and Post. They did not include the soil type since they are based on several different studies.	CT vs. NT	All crop systems	0.48
			All crop sys (no W-F)	0.57
			All Cont. monoculture	0.44
			All rotations (no W-F)	0.69
			All corn sys	0.55
			Cont. corn	0.44
			Rotation corn	0.62
			Rotation corn (no corn-soybean)	0.32
			Corn-soybean	0.90
			All wheat	0.32
			Cont. wheat	0.25
			Rotation wheat (no W-F)	0.74
			W-F	0.02
			All soybean rotations	0.78
			Cont. soybean	0.61
			Rotation soybean	0.84
			Rotation soybean (no corn-soybean)	0.77
			All rotation with grass, hay, pasture	0.19
VandenBygaart	BC	NT	Note: Sequestration rates are based on soil types, therefore crop rotation is not applicable.	0.13
et al. 2003	BIC			0.37
	DBC			0.63
	GL			0.28
	GBL			-0.2
	HFP			-0.3

	HG			-0.7
	LG			-0.09
	OG			0.35
	MB			0.90
	Western Canada			0.32
	Eastern Canada			-0.07
Campbell et al. 1996a	South-western SK/BC – fSL	CT vs. NT	Cont W vs. F-W	1.6 Over 11 years.
McConkey et al (2000)	Network on benchmark fields across SK		Elimination of fallow	0.1 to 0.26
		Adoption of NT		0.12 to 0.36

W-wheat; WW-winter wheat, F-summer fallow, Hy-high yielding CPS wheat, CF-chemical fallow, GM-legume green manure, Cont-continuous, NT – no till, CT – conventional till, WD – well draining, ID – imperfectly drained

There are two Project types potentially eligible under the agricultural soil carbon sink protocol. These are based on the crediting period and the date of change of farming practices relative to the beginning of the crediting period:

1. Project with soil-practice change after Project registration:
   In these Projects, baseline SOC can be measured at the commencement of practice change.

2. Projects with a practice change prior to Project registration but later than January 1st 2000:
   In these Projects sampling sites can be measured at the end of the first reporting period (i.e. 5 years) and all subsequent reporting periods but the original Project and soil baseline condition must be back calculated using either coefficients derived from NCGAVS or acceptable Models.

All data submitted to meet and maintain eligibility under a Project must be verifiable. Due to the large effort associated with determining and reporting measured or coefficient based baselines, and the large land base required to justify costs of measurement of Project impact on SOC, it is anticipated that individuals will apply as part of a group. It is anticipated that an aggregator, who employs or contracts qualified specialists (e.g. Professional Agrologist) to supervise, sign-off and participate in the Project work, will manage these groups.

Nitrous oxide emissions are quantified using a regional coefficient approach for all project types. ***(probably need more discussion in following section to rationalize N2O approach**).*

No till Projects that include land where the date of practice change is prior to 2000 are eligible only under a default coefficient approach, which is not included in this protocol.

Projects will be based on the physical area for which the Project Proponent can demonstrate ownership of carbon change Offset credits during the project.

For Sink Projects:

The Project Proponent for a sink project must state what mechanisms for dealing with non-permanence of GHG removals are applicable to this protocol.

The two mechanisms through which non-permanence can be dealt with are:

- The issuance of offset credits with a requirement to maintain the project level of carbon in the reservoir for a set period (the liability period)
- The issuance of temporary credits

A project proponent may also apply to have their project issued both offset credits and temporary credits. If this is the case, the areas proposed for each credit type must be explicitly delineated. Quantification will be performed and reported separately for each area.

1.2 Development approach and work plan

The development approach for a protocol for the quantification of greenhouse gas (GHG) emissions and removals attributable to agricultural soil carbon sink Projects in Canada under the measurement method was to complete a literature review of scientific papers and Agriculture Canada guidance papers provided by D. Haak, B. McConkey and other members of the Soil Technical Working Group.

Based on the review and knowledge of soils, a sampling strategy and statistical design for use within the protocol is developed. Procedures are specified for sample site selection, sample collection, sample handling, laboratory procedures and quality control of data. An assessment of economic feasibility is also made, and examples of Projects are presented for typical scenarios.

1.2.1 Development emphasis

Principle to the development of a quantitative protocol for the measurement of carbon reductions and removal enhancements by sequestration in farmed soils is the development of a sampling design and statistical approach that minimizes the amount of sampling and analysis required. This requirement focused research and sensitivity analysis on likely site variability and statistical tools with which to address the challenge.

The emphasis is to find the most efficient statistical design to produce statistically sound and defensible quantification, for as many soil types, eco-regions and soil-improving practices as possible, all at a cost that provides for the widest possible participation by the farming community.

1.2.2 Corporate identity

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1.2.4 Development team

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1.2.5 Roles and responsibilities

Role	**Team Member**
Team Leader	Leonard Leskiw M.Sc., P.Ag.
Literature Review	Allison McLean M.Sc., A.Ag
Statistics	Jeffrey Battigelli Ph.D., P.Ag.
General Assistance	Ron Sedor B.Sc., R.P.F.

All with Paragon Soils & Environmental Consulting Inc.

This information explains why the QM was developed using a particular approach and how the proponent plans to complete implementation.

Table 1.2 Options for quantification of sinks.

Option 1 Use appropriate regional agriculture soil carbon baseline with valid process model for Project effects.	Coefficient approach see Janzen
Option 2 Initial and final field measurements for Project quantification of SOC. Emissions calculations from records and factors or from coefficients.	Measurement approach
Option 3 Field measurement at Project approval and at end of project, with the use of project and business as usual SOC trend lines to back calculate to 2000. Coefficients are required to confirm results of backwards trends. Emissions quantified as above.	Measurement with back calculations using coefficients

For the work plan, the Project Proponent must define the project area; describe activities (including monitoring and measuring procedures for sinks, sources and removals) and timelines to be undertaken to implement the project. Where procedures follow this protocol, reference the protocol. Where procedures differ, describe and justify for approval by the Project Authority.

1.2.6 Project area and mapping

Prior to measurement, it will be necessary to stratify each Project site, based on ground condition similarities such as soil zones, SOC levels, soil drainage, topography, and farm improving practices. This will ensure sampling requirements and associated costs are kept to a minimum. All strata should be mapped and measured using basic ground based mapping technology (GPS; soils and topographic maps; aerial photos) on an appropriately scaled map (1:5,000 to 1:10,000) for the legal entity (e.g. quarter section) and each polygon identified (number or symbol) and described. All access routes and physical features of the overall site should be included on the map. The important, relevant characteristics of each polygon should be recorded, including soil profile description, topographic slopes, parent material, landscape position, slope, drainage, evidence of erosion, farming practice (may change), legal location information and area in hectares.

1.2.7 Sampling design considerations

The procedures in this protocol aim to provide a simple and cost-effective method for measuring carbon stocks in an agricultural soil carbon sink Project. The sampling approach used in these procedures involves the establishment of a series of sample points or ‘micro-plots’ within the designated areas (farm fields) of the Project.

A major challenge in accurately measuring SOC is measuring small changes against high background levels. There is considerable spatial variation over short distances (see Figure 1.1) plus there are possible measurement errors in sampling through to laboratory analysis. This can be partially overcome by taking many samples and determining the mean SOC levels within desired (95%) confidence limits. Confidence intervals are a measure of uncertainty in the mean estimate influenced by both variation and measurement error and are linked to the number of samples. Consequently, the strategy employed in this protocol is to present procedures that optimize sampling efficiency, that is, minimize sample numbers and maximize sample area. In many cases this necessitates pooling of farms. For examples used in this report and to keep the project attractive to farmers, the costs for soil sampling and analysis are kept below 20% of estimated returns for sequestering carbon. Thus, assuming CO_2 is worth $15/metric tonne (T), which equals $55/T SOC, the cost of measuring SOC per tonne is kept at <20% (<$11/tonne) or <$27.50/ha, assuming 2.5 T/ha SOC is sequestered over five years.

1.2.8 Statistical design and sampling

Statistical analysis is a critical part of the scientific process. Statistics provides assurance that a reported change is a measure of real change in SOC, not simply errors in measurement resulting in a difference.

Statistics provide evidence, for or against, changes in SOC by fixing the probability of making an error. Type I error, or the reporting a significant change in SOC where in reality there was none (i.e. a false positive), protects the purchaser of carbon credits. Alternatively, consideration of type II error or not reporting a change in SOC when there is one (i.e. a false negative) protects the producer (farmer) of carbon credits. Confidence intervals, derived from the acceptable type I error, are set at 95%, so that 95% of the time the interval will capture the true mean change in soil organic carbon in our samples and correctly evaluate the change in SOC. Additionally setting the power of the test at 95% to determine the minimum number of soil samples needed to reduce type II errors protects the producer by guaranteeing that if a change in SOC has occurred, then it will be detected 95% of the time given the sampling protocol. The end result is a statistical approach that fairly benefits and protects both the producer and purchaser.

Precision refers to the reproducibility of a method when it is repeated on a homogenous sample under controlled conditions. It can be expressed by standard deviation (SD) or coefficient of variation (CV) (Bergstrom - manuscript). Accuracy refers to the agreement between the amount of a constituent measured by a specific analytical method, and the amount actually present (Bergstrom - manuscript).

In a paired t-test approach samples are, in this study, spatially connected with each other. Therefore the paired t-test checks for statistically significant increases or decreases in the change in SOC. The result is a confidence interval around the mean estimate. If the confidence interval contains zero, such that there is no difference in SOC, then we conclude there is no significant increase or decrease in SOC over the period of time between the sampling events. A 95% confidence interval is used in this protocol at a resolution of 0.5 T SOC. This means that there is 95% confidence that a measured change of SOC greater than 0.5 T/ha is detected and real. It should be noted that paired t-tests are preferable to standard t-tests as they have more power to detect differences because of this spatial connection. If long-term trends, not incremental changes in SOC as discussed here, are desired, then time series analysis (such as ANOVA) would be necessary to describe the trend in observations.

Reliable measurements confirmed by statistical analysis are essential to verify that SOC is sequestered. Characteristics of and variations in land use related to crop and soil management, soil properties, landscapes, and climatic regime are key factors to be considered (Ellert et al. 2002). Point measurements of SOC provide the foundation of this measurement protocol, scaling up to landscapes and pools of farmers in a Project . Table 1.3 provides a summary of sampling methods found in the literature.

Table 1.3 Various sampling methodologies for determining soil organic carbon.

Reference	Projects	Design	Microsite Design		Background SOC ($T\ ha^{-1}$)
			Size	Sample No.'s	
Bricklemyer et al. (2005)	Montana dryland Wheat	Compare SCO in NT and CT	2 x 4 m 3 x 3 m	8 9	6.9 (CT) vs. 8.8 (NT) – Simpson, MT 14.4 (CT) vs. 18.2 (NT) – Ft. Benton, MT
VandenBygaart et al. (2006) (In press)	Que. – 2 sites Ont. – 2 sites Sask. – 2 sties	- Depth vs. horizon - Pooling - Analytical sub-sampling - Number of cores	4 x 3 m	12	All 0-20 cm depth. Que. 73-CL, 73-S Ont. 36-SL, 434-orangic Sask.36-BC, 34-depositional
VandenBygaart and Kay (2004)	Ontario	- Pre-plow and post-plow NT - 4 microsites - 4 textures - 2 drainage classes	4.2 x 9 m (4 plots)	30	All in 4400 T soil - SL(high carbon): 72-95 - SL (low carbon): 40 - SCL: 65-105 - SiCL: 80-110
Conant et al. (2003)	Tennessee Washington	Cultivated and forested	2 x 5 m 3 preferred	6 per plot	TN – cultivated: 18.2±0.85
Conant and Paustian (2002)	USDA Virginia	Grasslands Forested Farm County State National	18 cores/microsite 3 sites – 6 cores 2 sites – 9 cores		
Ellert et al. (2002)	Lethbridge Alberta	Recovery of added coal dust in a cultivated field	4 x 7 m 3 plots	6 per plot	18 (0-10 cm)
Ellert et al. (2001)	Canadian prairies	Over 250 microsites across Saskatchewan	2 x 7 m	6	
McConkey et al. (2000)	Saskatchewan	Network of benchmarked fields across SK	2 x 5 m	6	

A provincial and ecoregion perspective of topsoil depths, corresponding SOC mass and ranges is given in Table 1.4. It is evident that Brown and Dark Brown Chernozems and Gray Luvisols (not shown in table) have soils with <50 T/ha SOC but Black and Dark Gray Chernozems generally exceed this level. Also, it is apparent that there is considerable range in SOC content within soil zones. Similarly, topsoil (Ap horizon) depths range considerably within soil zones. Minimum topsoil depth in Brown and Dark Brown Chernozems is about 10 cm, whereas in other soil zones a minimum depth for selected sites could be about 15 cm.

Table 1.4 Summary of organic carbon contents in topsoil on mid-slopes in Alberta eco-regions.

Eco-region (number of sites)	Dominant Soil Group	Topsoil Depth cm	OC T/ha mean	OC T/ha range
Peace Lowlands (10)	Dark Gray	12-20	77	37-137
Boreal Transition (8)	Dark Gray	15-23	58	29-130
Aspen Parkland (9)	Black	13-33	89	11-197
Fescue Grassland (2)	Black	19-20	78	66-89
Moist Mixed Grassland (5)	Dark Brown	10-18	41	24-67
Mixed Grassland (7)	Brown	10-24	19	13-28

Source: AB Benchmark sites. Note: Topsoil includes A horizons (Ap, Ah, Ahe).

Figure 1.1 shows variation within a few metres in Ontario soils. Table 1.5 shows the variation typically found in prairie soils within a circle with a 2 m radius. Coefficient of variation (which is the standard deviation divided by the mean and multiplied by 100 to become a percentage) in topsoil depth commonly ranges from about 5 to 15% but can be higher. This considerable variation necessitates a sampling approach that reduces variability. The most applicable approach found is that proposed by VandenBygaart (see Figure 1.2) where a paired t-test is used to compare initial and future soil cores to measure SOC. Sample sites must be very close together (<10 cm apart) to be valid, but sites can be either in micro-sites, transects or scattered across fields. Placement of sites in mid-slope positions is recommended. If paired t-tests are not appropriate, as in ridge till, then a t-test could be used, which results in an increase in the number of samples required. For t-tests, micro-sites would have to be established (e.g. 2x4 m with 6 sample sites in each). Also it is preferable to take only one sample per site and the literature suggests this is possible.

Table 1.5 Examples of topsoil depths in the Peace River Region, Alberta.

Site	Slope	Position[1]	Ap 1	Ap 2	3	4	5	6	7	8	9	Mean	SD	CV%
593	1	U	13	14	13	14	15	15	14	14	14	14.00	0.707	5.05
		M	12	15	16	17	17	16	16	13	14	15.11	1.764	11.67
		L	14	16	20	20	18	20	20	17	16	17.89	2.261	12.64
594	5	U	20	21	21	23	22	22	22	20	23	21.56	1.130	5.24
		M	20	21	21	20	19	20	23	20	19	20.33	1.225	6.02
		L	20	21	23	22	21	24	23	24	23	22.33	1.414	6.33
595	2	U	15	19	18	16	16	16	15	15	17	16.33	1.414	8.66
		M	17	20	18	18	21	17	20	20	22	19.22	1.787	9.30
		L	15	16	17	16	19	21	22	19	16	17.89	2.472	13.82
598	3	U	13	18	15	15	18	14	16	15	16	15.56	1.668	10.71
		M	20	18	20	15	14	21	17	19	17	17.89	2.369	13.24
		L	21	22	19	18	20	21	18	20	20	19.89	1.364	6.86
599	2	U	20	32	24	22	22	20	19	23	24	22.89	3.855	16.84
		M	15	24	22	20	30	18	22	19	20	21.11	4.226	20.02
		L	12	9	13	11	16	45	15	13	14	16.44	10.910	66.34

[1] U=upper, M=middle, L=Lower positions, all on <5% slopes.

Important implications for sampling intensity are:

- Choose uniform areas (<5% slopes preferred). Steeper topography necessitates more sampling.
- Locate sample sites >100 m away from field margins; obstacles such as wetlands, building sites, roads, etc. The objective is to select sites with normal farming practice, avoiding headlands.
- Try to avoid sites with calcareous topsoils (this introduces more variability and necessitates extra sampling).
- Choose mod-slope positions to avoid eroded upper slopes and depositional lower slopes.
- Stratify sites by SOC content: keeping sites with low carbon in one pool is advantageous, or, in other words, fewer farmers and hectares are needed to make sampling economical.
- Higher carbon sequestration amounts due to either higher rates of sequestration and/or longer time periods over which sequestration occurs reduce sampling intensity (if SOC is doubled, sampling requirements are roughly halved).
- Strive for uniformity in selecting monitoring sites for either t-tests or paired-t tests, and the latter are strongly preferred to keep sample numbers lower (about half).
- When picking an exact sampling point, first check topsoil depths along a 2 m radius around the site to ensure topsoil depths are uniform and comparable to the field as mapped. Do not disturb within 1 m of the sample site to preserve its integrity.

- Composite sampling is not recommended because it precludes determination of soil variation.
- Sampling becomes relatively more expensive as SOC content increases, to the point where it becomes impractical to measure. Organic soils are not suitable for monitoring and soils with more than about 50 T/ha carbon (organic and inorganic) are probably not suitable to measure.

Table 1.6 shows the percentage variation about the mean for three levels of coefficients of variation. This information is used to determine sample numbers required to detect a change of 0.5 or 1 T/ha SOC. For example, at a CV of 15% to detect a change in SOC of 1% of the mean, 400 samples would be needed (1% of 50 T/ha SOC equals 0.5 T/ha SOC).

Table 1.6 Expected percentage variation about the mean (limit of accuracy) for different CV values at 95% confidence limits for different sample numbers (adapted from Wilding et al. 2001).

n	CV	10%	15%	20%	n	CV	10%	15%	20%
	α = .05					α = .05			
2	4.3	30	46	61	150	1.98	2	2	3
3	3.18	18	28	37	200	1.97	1	2	3
4	2.78	14	21	28	250	1.97	1	2	2
5	2.57	11	17	23	300	1.97	1	2	2
6	2.45	10	15	20	350	1.97	1	2	2
7	2.37	9	13	18	400 - 600	1.97	1	1	2
8	2.31	8	12	16	700 - 1500	1.96	1	1	1
9	2.26	8	11	15	1600 - 1700	1.96	0.5	0.7	1.0
10	2.23	7	11	14	1800 - 2000	1.96	0.5	0.7	0.9
15	2.15	6	8	11	2500	1.96	0.5	0.6	0.8
25	2.06	4	6	8	3000 - 3500	1.96	0.5	0.5	0.7
50	2.01	3	4	6	4000 - 5000	1.96	0.5	0.5	0.6
75	1.99	2	3	5	5500	1.96	0.5	0.5	0.5
100	1.98	2	3	4					

Table 1.7 shows the coefficient of variation reported for several studies. Most commonly the range is from about 10 to 20%. Only one study conducted analysis to determine CV in the laboratory (VandenBygaart 2000). Other studies listed in Table 1.7 determined CV for the entire study that combines field and laboratory components. It is noteworthy that most of these studies were conducted on soils with low (<30 T/ha) SOC.

Table 1.7 References regarding coefficient of variation.

Reference	CV	Comments
Bricklemyer et al. 2005	8-13%	Microsite variability 6 sites per microsite, 2 m apart in 2 x 5 m frame.

Conant and Paustian 2002	12-19%	Highest in site where recent conversion from forest to pasture.
Conant et al. 2003	6.4-20.7% (in cultivation-TN) 4.6-23.4% (in forests-TN) 10-96% (in forests-WA)	Microsite variability 6 cores per microsite, 3 microsites, 2 m apart in a 2 x 5 m frame (in Tennessee and Washington state).
VandenBygaart et al (2006) (in press)	7-16% (in Que., Ont., and Sask. Soils)	Laboratory CV was shown to be 7.2% in one case, with overall CV being 13.2%.
Bergstrom et al. (2001b)	27% for surface layer 47% for A horizon 40% for solum	Adjacent fields of contrasting tillage were stratified by soil series and drainage.
McConkey et al. (2000)	10-25% (not actually CV-see comments)	Subsamples were rerun, and found to be within 10-25% of the original value.

Several commercial laboratories were contacted to determine their levels of precision but only Norwest Labs provided helpful information. The following equation shows Norwest Labs' uncertainty information and Table 1.8 shows examples for 19 samples with organic and inorganic carbon.

$$U_{TC(95\%)} = \sqrt{(0.058[TC])^2 + (0.033)^2}$$

Equation 1.1 Norwest Labs' equation for uncertainty for analysis of total carbon.

$$U_{TIC(95\%)} = \sqrt{(0.092[TIC])^2 + (0.03)^2}$$

Equation 1.2 Norwest Labs' equation for uncertainty for analysis of total inorganic carbon.

$$U_{TOC(95\%)} = \sqrt{U_{TC}{}^2 + U_{TIC}{}^2}$$

Equation 1.3 Norwest Labs' equation for uncertainty for analysis of total organic carbon.

Table 1.8 Examples of total organic carbon variation for calcareous soils.

Sample	TOC wt%	Variation (±) (α=0.05)	Variation % of Value	Sample	TOC wt%	Variation (±) (α=0.05)	Variation % of Value
1	9.40	0.58	6.2	11	7.15	0.43	6.0
2	0.25	0.04	16.0	12	1.10	0.10	9.1
3	2.75	0.18	6.6	13	4.37	0.27	6.2
4	1.24	0.13	10.5	14	6.03	0.37	6.1
5	7.32	0.46	6.3	15	0.93	0.09	9.7
6	3.15	0.21	6.7	16	9.66	0.56	5.8
7	13.16	0.78	5.9	17	4.72	0.28	5.9
8	0.93	0.09	9.7	18	8.2	0.49	6.0
9	4.03	0.26	6.5	19	1.51	0.11	7.3
10	1.95	0.16	8.2	-	-	-	-

Source: Norwest Labs

Table 1.9 shows precision reported for 19 samples tested by the North American Proficiency Testing Program (2003).

Table 1.9 Comparison of precision of soil organic matter analysis based on results from an inter-laboratory study by the North American Proficiency Testing Performance Assessment Program.

Lab Number	SOM %	Lab Number	SOM %
1	3.50	13	2.10
2	1.80	14	3.10
3	1.62	15	NA
4	NA	16	1.80
5	2.30	17	1.93
6	2.00	18	1.80
7	1.58	19	2.00
8	2.00	20	1.95
9	1.60	**n =**	**18**
10	2.10	**mean =**	**2.14**
11	2.20	**SD =**	**0.55**
12	3.10	**CV% =**	**25.59**

Once the coefficient of variation is estimated for SOC measurements in a Project, information from table 1.6 can be used to generate a minimum sample numbers for soils with increasing SOC levels as presented in Table 1.10. Comparison of different sample numbers indicated that CV should be kept below 15% to keep sampling intensity reasonable. Reducing resolution from 0.5 T to 1 T/ha could help to reduce sample numbers for all soils but especially for those with > 50 T ha SOC.

Table 1.10 Minimum number of samples required to detect various SOC changes (95% confidence) with varying coefficient of variation.

Back ground SOC (T/ha)	CV 10%				CV 15%				CV 20%			
	1 T		0.5 T		1 T		0.5 T		1 T		0.5 T	
	% Δ	n	% Δ	n	% Δ	n	% Δ	n	% Δ	n	% Δ	n
10	10	6	5	25	10	15	5	50	10	25	5	75
20	5	25	2.5	75	5	50	2.5	150	5	75	2.5	250
30	3.3	50	1.6	200	3.3	75	1.6	400	3.3	150	1.6	700
40	2.5	75	1.25	200	2.5	150	1.25	400	2.5	250	1.25	700
50	2	75	1	200	2	150	1	400	2	250	1	700
60	1.6	200	0.8	1600	1.6	400	0.83	1600	1.6	700	0.83	2500
70	1.4	200	0.71	1600	1.4	400	0.71	1600	1.4	700	0.7	3000
80	1.2	200	0.62	1600	1.2	400	0.62	2500	1.2	700	0.62	4000
90	1.1	200	0.55	1600	1.1	400	0.55	3000	1.1	700	0.55	5500
100	1.0	200	0.50	1600	1.0	400	0.50	3000	1.0	1600	0.5	5500

1.2.9 Costing

Baseline Mapping Costs

Baseline mapping for 10,000 ha at a level 2- soil survey intensity (average 1 inspection per 10 ha) is estimated to cost about $5/ha.

Analytical and Reporting Costs

The following table lists estimated analytical costs. It is based on quotes from commercial laboratories. Collection costs are estimated by the authors. The 24-sample column represents costs for a two-section (512 ha) farm, the 400 sample column represents estimated minimum sampling costs for a pool of 10,000 ha.

Table 1.11 Sample laboratory analysis and sample collection costs for 1, 24 and 400 samples.

Parameter	Unit cost	24 Samples	400 Samples
Sample Preparation	$6.00	$144	$2400
Total organic carbon (SOC)	$18.00	$432	$7200
Total inorganic carbon (SIC)	$15.00	$360	$6000
Bulk Density	$8.50	$204	$3400
Field sampling and reporting	$52.50	$1260	$20,000
Total for SOC	$85	$2040	$34,000
Total for SOC and SIC	$100	$24,000	$40,000
Sample archiving	$10/month	$30/month	$110/month

Project Activity Documentation and Monitoring Costs
Fees and expenses for farm practice description and monitoring are estimated based on current commercial rates. It is expected that 2.5 days are needed at project initiation (year one) and 2 days at project completion (year five) per farm (averaged at two-sections or 512 ha). During years two to four there would be minimal consultation (0.5 day/year/farm) to review farm records and do a visual inspection of project fields. This totals six days at $1000/day for fees and expenses, resulting in a cost of $6000 or $12/ha.

Example Project/Farm Costs and Returns
The maximum project size for carbon sequestration is 100,000 T CO_2 (equal to 27,272 T C). In a farm pool, assuming most carbon is sequestered in soils, with minor sinks and reductions due to other factors, a target project scope for the SOC sequestration portion is set at a maximum of 25,000 T of SOC. Assuming an average SOC sequestration of 0.5 T/ha/yr (2.5 T/ha/5 yr), this translates to a pool size of 10,000 ha.

(Policy Concern: this project size constrains cost effectiveness of projects because the same total sample numbers could be extrapolated to perhaps as much as 100,000 ha and 250,000 T SOC).

Given the maximum project size of about 10,000 ha and an estimated 25,000 T of SOC sequestered, the total value of carbon is $1,375,000, based on $55/T SOC. Table 1.12 shows sampling requirements (at CV 15%) and soil monitoring costs (based on $55/T C) for various background levels of SOC and a resolution of 0.5 T/ha SOC. When background SOC levels increase to more than 60, 80 and 90 T/ha, sampling requirements increase to 10, 16 and 20 per quarter section, respectively. As a general guide, for soils with < 50 T/ha SOC, it appears that three sample sites per quarter section (64 ha) for at least 133 quarters (8512 ha and 400 samples) will meet statistical requirements (for paired t-test, 95% confidence limits with CV = 15%). Extending this sampling intensity to 10,000 ha (approximately 156 quarters) leaves 22 quarters (66 sample sites) as a “reserve” for substitution if some sites are destroyed or quarters withdrawn from the program.

Table 1.12 Costs and returns for soil monitoring and sequestering SOC.

Background SOC T/ha	n	Ha/sample	Soil monitoring costs at $100/sample	Soil monitoring cost as % of return
10	50	200	$10,000	<1%
20	150	67	$30,000	2.2%
30	400	25	$80,000	5.8%
40	400	25	$80,000	5.8%
50	400	25	$80,000	5.8%
60	1600	6.25	$320,000	23.3%
70	1600	6.25	$320,000	23.3%

80	2500	4	$500,000	36%
90	3000	3.3	$600,000	44%
100	3000	3.3	$600,000	44%

Note: Area 10,000 ha, SOC sequestration @ 2.4T/ha/5 yr.

Approximate costs for the baseline soil survey ($55/ha) and farmer consultation ($12/ha) total 12.4% of returns ($17/$137.50). Variable costs of soil sampling and analysis escalate from <6% of returns for <50 T/ha SOC to about 24% for 60 to 70 T/ha SOC, 36% for 80 T/ha SOC, and 44% for 90 to 100 T/ha SOC. Based on costs, the measurement protocol is most attractive (20% of returns) for soils with <50 T/ha SOC; marginal, at least 35% for soils with 60 to 80 T/ha SOC; and unattractive >50% for soils with >90 T/ha SOC. If sampling is doubled for any reason (for example, two layers vs. one, adding comparative controls for business as usual, two topographic positions vs. one, t-test vs. paired t-test) it increases cost to 40% of returns in the best case and jeopardizes the project.

There is also a risk involved in that all costs are incurred before returns are known. A farmer with 512 ha in a project, with soils with up to 50 T/ha SOC would pay an estimated total cost of $13,300. Returns would be $70,400, for a net benefit of about $57,000 or 81%, assuming there is sequestration of 2.5 T/ha SOC in 5 year.

Concern: This does not take into account potentially lower or higher sequestration rates, long-term liability with potential reversal, future monitoring/sampling costs considering inflation, brokerage fees, and risk of impact of possible climate change.

1.2.10 Soil sample collection

It is important that soil sampling occur at the same time of year for a given field. Sampling should be done in the spring before seeding or in the fall after crop removal. With a perennial crop spring or fall sampling is also recommended in case the field is seeded to an annual crop at the time of future sampling. Soil samples should be collected using a soil coring machine/tool, being careful not to compact cores to minimize effect on soil bulk density. Studies have shown that cores 5.4 cm in diameter are superior to 14.6 cm diameter for bulk density determination (NeSmith et al. 1986 in Campbell et al. 1996). Surface organic matter (i.e. crop residue, grasses etc.) must be removed prior to sampling as this will skew soil organic carbon concentration. Soil cores must be placed directly into plastic bags and kept cool during transport to the laboratory. Sampling intensity should be higher than statistically calculated to compensate for damaged, disqualified or terminated plot locations.

When a sample is being taken, a deeper core should be extracted to measure the topsoil horizon boundary and to bury an electronic marker. The hole should be filled in with subsoil and topsoil to match original depths. While filling the hole insert a short length of PVC pipe (5 cm in length, with a maximum diameter to fit the hole) below 10 cm to serve as a marker for future sampling. If the PVC pipe is hit while coring next time, the core is too close.

Locate the site with a GPS unit (high resolution preferred, within 30 cm).

There will be no movement of plots or micro-sites under this protocol, rather approximately 20% additional sites will be sampled and stored for later use if necessary. If a plot or site is destroyed (e.g. carbon levels abnormally changed for some reason) then it could be substituted with a stored initial sample and sampled at the corresponding location when other samples are collected. Also if some hectares (<20%) are removed from the project, the reserve of samples could be analyzed to maintain statistical integrity for the remaining fields.

1.2.11 Soil sample depth

The sampling strategy chosen is to sample one topsoil depth interval: soil surface, litter removed, to a depth below future disturbance depth but above the Ap horizon boundary. Inclusion of B or AB horizon material in the sample interval will greatly increase the variation and necessitate excessive sample numbers. In the prairies of western Canada this will likely mean 10 cm in the Brown soil zone and 15 cm elsewhere. Literature indicates that most SOC sequestration occurs in the upper 10 cm (see Table 1.13). Campbell et al (2000) suggest that SOC changes below 15 cm should not be included in determination of SOC sequestration.

In eastern Canada the sample interval will likely be 20 to 30 cm, depending on cultivation depth during conventional tillage. As above, samples should be as deep as possible but above the Ap horizon boundary.

In either region if there are concerns about losses or gains of SOC in the B horizons (or below topsoil sampled), then a sampling program should be implemented. If SOC levels are < 20 T/ha, sampling requirements will be minimal. On the other hand it SOC levels are > 50 T/ha at the lower depth interval, sample numbers will be too excessive to warrant sampling.

Table 1.13 Literature review of depth of carbon sequestration.

Reference	Region	Comments
Campbell et al. (2000a)	Saskatchewan	SOC occurs primarily in top 15 cm, especially top 7.5 cm.
Bergstrom et al. (2001b)	Manitoba	Significant difference in SOC found in 0 – 8 cm in NT vs. CT in well

		drained soils. No significant difference in SOC in entire A horizon in NT vs. CT in well drained soils.
Carter et al. (1997)	Eastern Canada	63% SOC in 0-20 cm
Angers et al. (1997)	Eastern Canada	change in SOC in top 15 cm
Campbell et al. (2000)	Saskatchewan	changes in SOC only significant in 0 – 15 cm depth, not significant in 15 – 30 cm.
Campbell et al. (1996)	Saskatchewan	SOC tended to increase in 0 – 7.5 cm depth but not in 7.5 – 15 cm depth.

1.2.12 Soil carbon sample preparation

Prior to analysis samples need to be air-dried for 24 hours at 60ºC (Plante et al. 2006; Bates 1993). Norwest Labs uses 40 to 50 ºC for 24 hours in Alberta. Other provinces may have different standards. It is important to note the temperature used and to keep it the same for each batch of samples within a Project. The entire soil sample should be sieved to 2 mm. Stones and coarse fragment content greater than 2mm must be weighed and deducted from the soil volume and mass (Post et al. 2001; Bergstrom et al. 2001a; Monreal et al. 2005). This estimate can be done using the method outlined by Vincent and Chadwick (1994). Roots and identifiable organic matter should be removed from samples, as inclusion of this will skew soil organic carbon concentrations. A portion of the cored soil sample should be oven dried to 105ºC to determine gravimetric water content. This information can then be used in the determination of bulk density ($\mathbf{D_B}$) on a dry weight basis. It is important that only the mineral soil undergo organic carbon analysis. Samples analyzed for organic carbon should be finely ground and homogenized and a sub-sample taken for analysis (Monreal et al. 2005; Bergstrom et al. 2001a; Bergstrom et al. 2000b; Ellert et al. 2002).

A portion of the air-dried, homogenized, ground samples should be archived for future reference, and stored in a secure manner.

1.2.13 Soil bulk density

To convert soil organic carbon concentration to a mass of soil C, soil bulk density is required (Campbell et al. 1996; Post et al. 2001; Monreal et al. 2005). Bulk density can be calculated from the dry weight of the soil sample and core volume (known from core diameter and sample depth) (Bergstrom et al. 2001a; Bergstrom et al. 2001b). SOC should be compared on an equivalent mass basis, adjusting initial and final paired samples to the lowest bulk density (Equivalent Mass Method: Bergstrom – manuscript).

An important fact is that the density of the sample is needed, hence the preference to reduce error by determining SOC and bulk density in the same sample.

1.2.14 Soil organic carbon measurement in calcareous soils

Accurate measurement of SOC is essential in quantification of changes due to change in practice. There are several methods available for SOC analysis. These include dry combustion, wet digestion and redox methods. Within the literature the dry combustion using automated instrumentation (i.e. LECO or Carlo Erba) is the most commonly used method and it appears to be the best method. NAPT (North American Proficiency Testing) results indicate that is the most precise method for organic carbon determination. For SOC measurement, one of the following two methods should be used for all monitoring within a project:

1. Soon and Abboud (1991) outline a method using dry combustion to determine organic carbon concentration. A portion of the soil sample is analyzed for total carbon (i.e. combustion at 1000ºC) (Nelson and Sommers 1996). The other portion is heated at 425ºC for 4 hours to oxidize organic matter then analyzed for total carbon. Since the organic carbon has been oxidized, this results in the determination of inorganic carbon. Organic carbon is the difference between total carbon and inorganic carbon (organic C = total C – inorganic C) (Yang and Kay 2001; VandenBygaart and Kay 2004).

2. Pre-treatment of soil samples with acid (HCl, H_3PO_4 (Yeomans and Bremner 1988) and H_2SO_3 (Bisutti et al. 2004; Nelson and Sommers 1996)) to remove inorganic carbon, which allows for total carbon = organic carbon. Samples are analyzed for total carbon using dry combustion. Tiessen and Moir (1993) outline a method in which 2 *M* HCl is used to pretreat soil samples (Kachanoski 1996; Ellert et al. 2002; Bergstrom et al. 2001a; Bergstrom et al. 2001b).

If a Proponent wishes to use another reliable and suitable method for SOC analysis, the Project Authority must approve the method.

It is essential that the same method be employed to determine SOC at the beginning and end of the carbon sequestration period as well as for verification and the liability period. This ensures that a true change in carbon is detected. If different methods are used, it may be that one method provides higher or lower values or is more or less accurate than the other and a perceived change in soil carbon may be due to the analytical methods, not carbon sequestration.

1.2.15 Organic carbon in non-calcareous soils

Since there are no carbonates (inorganic carbon), total carbon is equal to organic carbon. Total carbon can be determined on the soil samples by dry combustion at 1000ºC – see Nelson and Sommers 1996 for method (Monreal et al. 2005; Izaurralde et al. 2001; Carter et al. 1997).

1.2.16 Particle size analysis (optional)

If a proponent wishes to separate soils into sandy and clayey soils, particle size analysis needs to be determined. There is a direct relationship between clay and SOC content (Campbell et al. 2000). Clayey soils tend to sequester more carbon than sandy soils and should be grouped accordingly. Campbell et al. (2000) suggest that when examining changes in soil carbon content that soil texture should be measured and used in conjunction with covariance analysis to differentiate between textural and treatment effects. Particle size analysis (PSA) could be determined on soil samples using one of two methods:

1. Pipette Method (Sheldrick and Wand 1993).
2. Hydrometer Method (Sheldrick and Wand 1993).

1.2.17 Back calculations of baseline conditions

Specified greenhouse gas baselines for Project with crediting periods prior to 2006 will be established initially by back calculating to 'business as usual' carbon levels using coefficients for specified practices.

1.2.18 Methods to determine CO_2 Equivalents for Sources

Reductions and removal enhancements for GHG emissions will be calculated from records using coefficients for specified factors. CO_2 equivalents for inorganic CO_2 (CO_2 from vehicle and equipment emissions, can be calculated using:

- Coefficients for direct and indirect energy as per Bobbi Helgason (2005), or

- Emission reductions can be quantified as the differences between the sum of emissions in the baseline scenario and the sum of removal enhancements or emissions attributable to the soil-improving practice.

1.2.19 On-site sources

On site sources of GHG consist of emissions from farm activities, including seeding, herbicide application through to harvesting of crops.

Release of nitrous oxide (N_2O) from fertilizer and methane (CH_4) from manure applications is not addressed in this protocol: it is being quantified by another part of the working group.

1.2.20 Off-site sources

Offsite sources are limited to trucking of product and inputs, where the Proponent owns the vehicles. Farm records will provide the necessary documentation of fuel consumed. Factors to transform fuel usage to CO_2 emission equivalents will be based on coefficients.

1.2.21 Confidence level of carbon measurements

In this protocol, the overall target error acceptable in field measurements is set so that the estimate of organic carbon mass will fall within 0.5 T of the actual mean at least 95% of the time. In practice, this means that site sampling intensity must be sufficient to produce estimates within this level of confidence. This can be achieved by ensuring that sampling plots are properly stratified and of a sufficient number and that sampling intervals are over a sufficient number of years.

(Concern: due to high analytical costs is it possible to reduce resolution to 1T?)

1.2.22 Interpolation of soil sample analysis results to various scalable units:

Stratification and variability are both key to developing a cost effective measurement protocol that can best characterize national GHG inventories.

Due to the level of response of some prairie soils to zero till and other agricultural soil carbon sink, measured Projects under the Offset System will most likely initially include prairie soil types. Target prairie soil types will include the brown, dark brown, black, dark gray and gray soils. Non-prairie regions in general will require more data to establish suitable physiographic zones, soil groups and farming practices that will yield significant carbon sequestration on a consistent basis.

It is proposed that the Terrestrial Eco-zones of Canada (Ecological Stratification Working Group 1996) for identifying polygons. Eco-districts are biophysical landscape units having shared climatic, landform, topographic, edaphic, and agricultural characteristics (Ecological Stratification Working Group 1996). This is a standard, nationally recognized system, which has been used extensively in the past for identifying soil units. It has been demonstrated that resource areas within this scale provide meaningful results for the assessment of impact of land use and agricultural practices on resource quality (Izaurralde et al. See map Annex 9.

1.2.23 Uncertainty assessment methodologies

There are three main areas of uncertainty:

- Uncertainties related to the parameters and assumptions used to create baselines.

- Uncertainties related to the accuracy of measurement of soil carbon. This can be dealt with through sampling and statistical design of each Project, however costs become excessive in soils with high levels of SOC.

- Uncertainties related to climate change and potential for maintaining sequestration rates experienced to date into the future.

1.2.24 Reporting

The following Sources, sinks and reservoirs will be reported:

- Sinks - soil organic carbon
- Emissions - CO_2 equivalents for inorganic CO_2 including vehicle emissions, and on farm equipment.

Glossary of New Terms and Definitions

Crediting period –means the BAU baseline date to the end of year 5.

Contract date –means the date or year of signing of the contract.

SOC –means total soil organic carbon.

Soil improving practices –means any of the following farming practices:

- reduced till- ridge and strip till
- zero till
- reduced fallow frequency and weed management (herbicides versus tillage)
- incorporation of nitrogen fixing plants in crop farming practices
- conversion from till or zero till to permanent perennial forage

2 Section II Quantification Development and Justification

Based on the project's description and scope, this section will identify the baseline scenarios and SSRs. Each step will provide justification of the project's final quantification equations. The selections made by the Project Proponent must apply the good practice guidance, if available (guidance on selection and application of good practice guidance is provided in Annex 2). Where good practice guidance is not used in this section, the Project Proponent must provide criteria and procedures for justifying their selection. This section will provide justification around the information that will be provided in the detailed project description in Section III.

Project SSRs

2.1 Identification of Sources Sinks and Reservoirs (SSRs) for the project

Allows PA to understand how decisions were made to identify, assess and select the possible project-level SSRs.

The principle carbon sink, to be quantified is soil organic carbon. Soil organic carbon influences several important soil properties including nutrient availability, soil structure, erosivity, and moisture retention. It is closely related to plant production in agricultural ecosystems and soil carbon is an important dynamic pool in the terrestrial carbon cycle (Ellert et al. 2002). Globally, soils contain more than twice as much carbon as the atmosphere (Schimel 1995). The soil and atmospheric pools are intricately linked, so that the loss of soil carbon increases atmospheric CO_2, while a gain in soil carbon removes CO_2 from the atmosphere (Ellert et al. 2001). Soil carbon sequestration rates may be affected by ecosystem development or by management practices, thereby affecting the soil – atmosphere balance. Estimates suggest that management strategies to enhance potential rates of soil carbon sequestration over extensive cropland areas may result in net carbon sequestration ranging from 0.2 to 0.5 T ha^{-1} yr^{-1} (Sampson and Scholes 2000). A challenge in measuring carbon changes in soils is the large relative quantity of carbon in topsoil, compared to annual inputs of plant carbon and outputs of CO_2 (Ellert et al. 2002).

Table 2.1 Agricultural sector coefficients comparison GHG sources by soil type.

Source	Practice	Soil Type	Coefficient	
	GHG FARM	CANSIS	Crop Year	Fallow Year
Direct Fuel	Conventional Till	Brown	2.02*81=163.62	1.62*81=131.22
"	"	Dark Brown	2.02*81=163.62	1.62*81=131.22
"	"	Black, Gray	2.63*81=213.03	2.35*81=190.35
"	Zero till	Brown	1.42*81=115.02	0.34*81=27.54
"	"	Dark Brown	1.42*81=115.02	0.34*81=27.54
"	"	Black, Gray	1.43*81=115.83	0.93*81=75.33
"	Minimum Till	Brown	1.78*81=144.18	1.16*81=93.96
"	"	Dark Brown	1.78*81=144.18	1.16*81=93.96
"	"	Black, Gray	2.39*81=193.59	1.71*81=138.51
herbicide use	Conventional Till	Brown	0.16*43=6.88	0
"	"	Dark Brown	0.16*43=6.88	0
"	"	Black, Gray	0.16*43=6.88	0.6*43=25.80
"	Minimum Till	Brown	0.23*43=9.89	0.07*43=3.01
"	"	Dark Brown	0.23*43=9.89	0.07*43=3.01
"	"	Black, Gray	0.23*43=9.89	0.11*43=4.73
"	Zero till	Brown	0.46*43=19.78	0.78*43=33.54
"	"	Dark Brown	0.46*43=19.78	0.78*43=33.54
"	"	Black, Gray	0.46*43=19.78	0.6*43=25.80

** Cold Dry Temperate ***Compound values are practice over fallow, Note: GHG compound values are gigajoules per hectare, followed by emission factor in kg CO_2 per gigajoule per ha. Multiply gigajoules by factor to get kg CO_2/ha/yr.

To verify that soil carbon is sequestered, reliable measurements confirmed by statistical analysis are essential. Characteristics of variations in land-use, crop and soil management, soil properties, landscapes, and climatic regime are key factors to be considered (Ellert et al. 2002). Point measurement of soil carbon is the foundation of this measurement protocol, scaling up to landscapes and broader geographic regions.

Principle emissions to be quantified are inorganic emissions of GHG from the burning of fossil fuel during tilling, seeding, the application of herbicide, fertilizer, and harvesting.

2.1.1 Elements that will not be quantified

Removal of methane through oxidation in soils will not be individually quantified as SOC is being measured.

Emission of CO_2 from aerobic decomposition of organic matter in soils will not be individually quantified as SOC is being measured.

Off farm leakages related to transportation and storage of farm products or inputs may or may not be quantified, dependent upon the control and ownership of the product or input.

Nitrous oxide and methane emissions will not be quantified as these components are being addressed by coefficients (see ___).

Organic soils and mineral soils with high levels of SOC (perhaps >50 T ha^{-1}) will be excluded from quantification and project eligibility due to the lack of analytical precision and high cost of measurement.

2.1.2 Sites where GHG reductions may not occur or be verifiable:

Specific soil types in several farming regions have either evidenced no consistent sequestration of GHG reductions as a result of the implementation of soil-improving practice, or no refereed publications could be found to support the potential for GHG reductions. Poorly drained soils with deep organic rich horizons (greater than 100T/ha SOC) are one example of a potentially non-verifiable site.

If the Project activities are not expected to result in significant GHG emissions to the atmosphere from soil carbon relative to the expected aggregate (or net) emissions reductions and removal enhancements, then they need not be monitored.

a) Using the life cycle categories listed below, list and describe the SSRs that are controlled, affected or related to the project (Column 2 in Table 2.1c). If good practice guidance is not used, justify any departure from these life cycle categories by providing criteria and procedures used to evaluate and select the SSRs.

The Project Proponent must evaluate all SSRs that could be controlled in the project, related to it (e.g. by flows of energy or mass), or affected by the project (i.e. by changes in demand or supply for products or services associated with the project).

It is required that at a minimum, the following life cycle categories of SSRs <u>must</u> be applied:

- Upstream SSRs during project. This includes the production of project inputs (fuel, electricity, etc. used on an on-going basis during project/baseline system operation), and transportation of project inputs to project site.

- On-site SSRs during Project. This includes activities related to operation of the project/baseline (e.g. fuel combustion, capturing CO_2 from a process and storing it in a reservoir, etc.), and maintenance.

- Downstream SSRs during Project. This includes transportation of product(s) from the project/baseline site.

All SSRs that can be included within the scope of the project should be included at this stage. The Project Proponent may also evaluate other SSRs that were a result of construction or decommissioning of the project.

A process-flow diagram can be used to illustrate the various SSRs that are included as part of the project that establish whether a SSR is controlled (i.e. within the project margins), related (i.e. connected to the project via material or energy flows), or affected (i.e. SSRs typically downstream of the project who's emissions profile will be changed by the execution of the project).

This information can be provided in the following table:

Table 2.1c Identification of controlled, affected, or related SSRs for the project

1. SSR	2. Description	3. Controlled, Related or Affected
Upstream SSRs		
Source or removal	Increase or reduction of emissions from transportation of farm inputs	Related if delivered by off-farm supplier or Controlled if obtained by farm operator
Source or removal	Increase or reduction of emissions from equipment manufacture	Related
Source or removal	Increase or reduction of emissions from pesticide manufacture	Related
Source or removal	Increase or reduction of emissions from herbicide manufacture	Related
Onsite SSRs		
Sink	Sequestration of CO_2 from soil-improving practices	Controlled
Sink	Sequestration of CH_4 in soil from natural processes	Controlled
Source or removal	Increase or reduction of emissions from farm machinery and vehicles	Controlled
Downstream SSRs		
Source or removal	Increase or reduction of emissions from truck transportation of product	Related if delivered by off-farm supplier or Controlled if obtained by farm operator
Source or removal	Increase or reduction of emissions from rail transportation of product	Related
Source or removal	Increase or reduction of emissions from storage of product	Related
Source or removal	Increase or reduction of emissions as an indirect affect on markets	Affected
Other		
Various SSR's from	To be assessed by other members of	Controlled

manure and fertilizer applications	working group	

***Informative annexes to support rationale and/or justification should be referenced in the table.**

For Sink Projects:

Sink projects that are applying for both offset credits and temporary credits must identify their project sinks in each area separately.

Baseline Scenario

2.2 Identification of the baseline

A baseline reflects a reasonable representation of the conditions most likely to have occurred during the registration period in the absence of the project. Therefore the Project Proponent is required to evaluate several baseline scenarios and identify the most appropriate. The justification for excluding baselines should demonstrate why other baseline scenarios are unrepresentative or impractical.

*When establishing the baseline, the Project Proponent must take into consideration all requirements established by provinces/territories, municipalities, regional boards etc. in regulations, permitting requirements, operating certificates, etc. The requirements to be considered relate to all factors surrounding the project (e.g. noise, odour, etc.) and are not limited to those relating to GHG emissions. If the implementation of the project is required to meet such obligations, it may not meet the incremental criteria for the Offset System (see section 2.4 of the Project Document). However, if the project is required but clearly exceeds the results necessary to be in compliance with the relevant obligations, the incremental emission reductions may be eligible for Offset Credits. In addition, the PA may establish a **"normalized baseline"** to be used by all Project Proponents for certain project types where it is clear that a jurisdiction or a few jurisdictions have taken regulatory or other steps to protect the environment that are significantly in advance of what is happening in most other jurisdictions. In these cases, Project Proponents only need to state that they are using a required pre-established baseline. Normalized baselines will be posted on our website as they become available (the website will be linked through: www.climatechange.ec.gc.ca).*

[If a normalized baseline has not been established by the PA for a project type that is subject to such differences between jurisdictions, the Project Proponent can develop a normalized baseline for the project. The normalized baseline must be accompanied with sufficient justification for the PA to evaluate the validity of the baseline.]
(Please note: this is still under consideration, your thoughts on this are welcome)

The PA will also be able to assess how the selected baseline helps ensure that emission reductions or removals meet the 'real' eligibility requirements identified in Section 2.3 of the Project Document.

For a Project to be eligible to participate in the Offset System, the project must meet a set of eligibility criteria specified in the rules of the system. Project Proponents will be required to ensure that their Project meets these eligibility criteria before proceeding with the development of a Project Document using this Protocol.

Evidence in the form of photos, records, aerial photos and or satellite imagery must be presented to show that prior to January 1, 2000 the Project area was farmed in a manner such that carbon sequestration can be increased by the application of soil improving practices, and will provide a history of tillage and other associated activities since then.

The intent is that a change in farming practices takes place under the term of the Project and is sustained or improved to sequester carbon through the liability period.

An independent third party must inspect and confirm the change to soil improving practices.

Baseline selection will be based on farming practices and equipment utilized at the time of the inception of the Project. The baseline scenario must meet the general IPCC definitions as per Revised 1996 Guidelines for National Greenhouse Gas Inventories: Workbook Land Use Change and& Forestry 5.31-5.33. See Annex 3.10 1.

Business as Usual/Baseline

To be a part of the measurement based approach for carbon sequestration a number of factors have to be considered. A farmer has to have had a change of practice (i.e. conversion to zero till from conventional till) starting on or after the year 2000. If a farmer was practicing zero till prior to year 2000, the farmer does not qualify for the measurement based approach unless another change of practice that further sequesters carbon (i.e. reduction of summer fallow) occurs. The farming practice in place prior to year 2000 is considered the baseline. This baseline or “business as usual” rate of carbon change has to be quantified. Extensive literature reviews and searches were conducted to see if experimental data could be used to determine these baselines under a variety of soil great groups, soil textures and farming practices. Some information was gathered and it is presented in Table 1.2a.

The use of a modeling approach, such as the use of CENTURY is also an option. CENTURY is a widely used and accepted model for soil organic matter dynamics (Parton et al. 1987 in McConkey et al. 2000). Overall, SOC estimates simulated by CENTURY correspond with measured soil organic carbon (McConkey et al. 2000). Other models (eg. SOCRATES, ECOSYS) are available and may be used subject to approval by the Project Authority.

Another approach would be to establish controls continuing the initial practice, and comparing SOC in these soils to those of the Project soils. This would require a complete set of soil analysis, which doubles the cost, and there is no way of confirming that soils being compared contained identical SOC levels and equilibria prior to implementation of the first carbon sequestration practice on the Project farm. Furthermore, these "controls" would likely be farmed by farmers not participating in the project. This makes the use of controls impractical.

2.2.1 Baseline Scenarios

Baseline selection will be based on farming practices and equipment utilized at the time of the crediting period of the Project.

Once approved SOC measurement based Projects must be monitored on an annual basis to assess changes in emission sources only, and to ensure that soil improving practices are implemented as per Project specifications.

2.2.2 Justification for Baseline Selection

In the measurement protocol the initial sampling provides the "baseline" SOC levels. Changes in SOC are determined on a "go forward" basis. Back calculations can only be determined by applying coefficients or soil models.

At issue is the method to determine baseline SOC storage, sequestration or reduction rates, and the number of years of farm records required to substantiate the business as usual practice. There is not enough data to support back calculation based on measurements for pre 2006 Projects. Control comparisons for these Projects are not practical. It may be that a significant proportion of pre-2006 Projects may only be feasible using the coefficient approach.

2.2.3 Baseline Scenario Statement

The fundamental baseline reference condition or business as usual is:

- full tillage farming.

Comparison baseline scenarios include any of the following soil improving practices where a shift in farming practices occurs:

- <u>reduced till- ridge and strip till</u>
- <u>zero till</u>
- <u>reduced fallow frequency and weed management (herbicides versus tillage)</u>
- <u>incorporation of nitrogen fixing plants in crop farming practices</u>
- <u>conversion from till or zero till to permanent perennial forage</u>

Comparison baseline scenarios are eligible for a Project where there is a shift in farming operations from a lower carbon fixing practice to a higher practice. Practice eligibility is specific to soil types.

> **(a) Describe and justify what would have happened in the absence of the project for the baseline types that were selected (Column 2 of Table 2.2). If good practice guidance is not used, justify any departure from these good practice baseline scenario(s). Justify criteria and procedures used to evaluate and select the most appropriate baseline scenario.**

The PA may prescribe baseline scenario(s) for the project. For example, projects that occur in areas covered by the list of Climate Change Incentive Measures will be prescribed a performance standard above which they can be considered for Offset System credits. In these cases, Project Proponents only need to state that they are using a PA-required baseline.

The Project Proponent must evaluate the following list of potential baseline scenarios:

- A baseline scenario that is based on a <u>historic benchmark</u>: This is typically site-specific and can be constructed to reflect reductions/removals in a base period, for example average emissions between 1990 and 2000. This historic benchmark approach assumes that past trends in emissions and/or carbon stock changes will continue into the future.

- A baseline scenario based on a <u>performance standard</u>: This assumes the typical emissions profile for the industry or sector is a reasonable representation of the baseline scenario. An assessment of comparable activities within a given industry or sector is necessary.

- A baseline scenario based on a comparison approach: This uses actual measurements of parameters from a control group (e.g. plot of forested land, space heating natural gas consumption per square metre, etc.) to compare with the project. Emissions or removals from the control group are monitored throughout the project and compared with the emissions from the project site to determine the reductions/removals. Such a control group can be used with more than one project. This approach is considered to be impractical for the measurement approach.

- A projection-based baseline scenario: Projections of reductions/removals in the future can use a variety of techniques, from simple straight-line growth assumptions to complex models. Forward-looking scenarios can be specified in terms of a set of constant parameters or can vary over time according to pre-defined procedures.

- Baseline scenarios already registered/validated for similar projects: These are typically posted on the Offset System web site in other quantification methodologies or may be contained in other Offset System Quantification Protocols.

- Other: Project Proponents may have other approaches for developing a baseline scenario.

Note: Functional equivalence must be used by demonstrating that the project and the baseline are comparable in terms of products and/or activity levels. For example, the baseline should be capable of providing the same quality of products or services as the project. Annex 4 provides more detail on how functional equivalence is determined and provides examples of some common metrics that can be used to establish functional equivalence.

(b) Describe and justify whether the baseline scenario(s) are static or dynamic (Column of Table 2.2).

Baseline scenarios can either be static or dynamic. A static baseline establishes an emissions profile for the baseline activities that does not change during the registration period.

The emissions profile of a dynamic baseline will change periodically during the registration period.

Project Proponents will list whether any of the baseline scenarios evaluated above are static or dynamic and justify why this is appropriate.

Note: Project Proponents' assessment of baseline scenario(s) should include the likelihood of an event occurring beyond their control that would significantly affect the reductions/removals from their project (e.g. an extended severe drought). In these cases, a baseline scenario that can be easily adjusted to account for this event would be preferable to one that cannot.

> **(c) For the baseline scenarios provided above, justify why each one should be accepted or rejected as being the most appropriate / inappropriate (Column 4 in Table 2.2). If good practice guidance is not used, justify any departure from these baseline scenario(s) by providing criteria and procedures used to evaluate and select the baseline**.

Project Proponents must justify the most appropriate baseline scenario. Data availability, reliability and limitations need to be evaluated. Other criteria and procedures for identifying and justifying the most appropriate baseline may be developed and included.

All known sources, sinks and reservoirs other than those currently being worked on by other Working Groups are included.

This information can be provided in the following table:

Table 2.2 Possible Baseline Scenarios for Estimating GHG Emissions without Project.

These baselines are for measured changes in SOC due to soil improving practices where Project timing permits, and the use of coefficients where no other option remains.

1. Baseline Option	2. Description	3. Static / Dynamic Baseline	4. Accept or Reject and Justify *
Historic benchmark	May be established for SOC at first set of measurements for Projects for 2006 and beyond	Baseline may be dynamic, but is unlikely to be verifiable in a statistically sound manner at reasonable cost	Assume baseline is static
Performance standard			None available by soil group.
Comparison	Not feasible	Baseline may be dynamic, but is unlikely to be verifiable in a statistically sound manner at reasonable cost	Assume baseline is static.
Projection-based	May be required to back calculate BAU SOC for Projects commencing before 2006.	Baseline may be dynamic or static, dependent upon coefficient values.	Accept with reservations re. conservative nature of coefficients and their use with real measurements
Already registered			
Other	Measured approach for SOC may be feasible where SOC is very low and BAU contains significant inputs	Dynamic	Accept and monitor where appropriate.

***** Informative annexes to support rationale and / or justification should be referenced in the table.
Source: ***Project Proponent or company's name and date***

Baseline SSRs

2.3 Identification of SSRs for the baseline

Allows PA to understand how decisions were made to identify, assess and select the possible baseline-level SSRs.

> **(a) List and describe the SSRs that are controlled, affected and related to the baseline (Columns 1 and 2 in Table 2.3). If good practice guidance is not used, justify criteria and procedures used to evaluate and select the baseline SSRs.**

When the SSR in the project and baseline are the same, similar criteria and procedures can be used for both.

Sinks for all baselines are limited to carbon sequestration in soil under soil improving practices.

Sources for all baselines are limited to non-biological GHG from vehicle and equipment emissions used on-site (within Project boundaries).

Sources for all baselines are limited to GHG from vehicle emissions, and transportation of product to or from the Project site where the Proponent is the owner/operator. Due to the relative unreliability of potential record sources, as well as potential variability in tonne miles, transportation of product/inputs by non-owner/operator is excluded.

(a) Explain how the SSRs are controlled, related or affected by the baseline (Column 3 in Table 2.3).

Project Proponents will describe how the SSRs are controlled, related or affected by the baseline. All SSRs that can be included within the scope of the identified baseline should be included at this stage. Indirect reductions/removals can be included as affected or related sources, but the Project Proponent will have to justify that the baseline influences these sources.

A process-flow diagram can illustrate the various baseline SSRs and the boundaries that establish whether a SSR is controlled (i.e. within the baseline boundary), related (i.e. connected to the baseline via material or energy flows), or affected (i.e. SSRs typically downstream of the baseline who's emissions profile will be changed by the activities in the baseline).

This information can be provided in the following table:

Table 2.3 Identification of SSRs controlled, affected and related to the baseline.

1. SSR	2. Description	3. Controlled, Related or Affected
Upstream SSRs		
Source or removal	Increase or reduction of emissions from transportation of farm inputs	Related if delivered by off-farm supplier or Controlled if obtained by farm operator
Source or removal	Increase or reduction of emissions from equipment manufacture	Related
Source or removal	Increase or reduction of emissions from pesticide manufacture	Related
Source or removal	Increase or reduction of emissions from herbicide manufacture	Related
Onsite SSRs		
Sink	Sequestration of CO_2 from soil-improving practices	Controlled
Sink	Sequestration of CH_4 in soil from natural processes	Controlled
Source or removal	Increase or reduction of emissions from farm machinery and vehicles	Controlled
Downstream SSRs		
Source or removal	Increase or reduction of emissions from truck transportation of product	Related if delivered by off-farm supplier or Controlled if obtained by farm operator
Source or removal	Increase or reduction of emissions from rail transportation of product	Related
Source or removal	Increase or reduction of emissions from storage of product	Related
Source or removal	Increase or reduction of emissions as an indirect affect on markets	Affected
Other		
Various SSR's from manure and fertilizer applications	To be assessed by other members of working group	

* Informative annexes to support rationale and / or justification should be referenced in the table.
Source: Project Proponent or company's name and date

Project and Baseline SSRs

2.4 Selection of relevant[1] SSRs to be included for quantification of the project and baseline

Allows the PA to understand how the SSRs were compared between the project and baseline. With the information provided, the PA should be able to assess the application of the relevance principle. This section will demonstrate which SSRs should be quantified, and justifies why certain baseline or project SSRs are excluded from the quantification procedure. This comparison will allow an

[1] The Relevance principle is defined in the introduction of this guide.

assessment of whether the reductions/removals from the project meet the ‘incremental[2]’ eligibility requirement.

Sinks for all Baselines are limited to carbon sequestration in soil under agricultural soil improving practices.

Sources for all baselines are limited to GHG from on-site equipment and vehicle emissions.

Vehicle emissions from proponent owned transportation of inputs or products to and from the Project site are also included.

(a) List and compare all controlled, affected or related baseline and project SSRs for calculation (Columns 2 and 3 of Table 2.4).

This comparison of baseline and project SSRs is to help Project Proponents determine which SSRs are relevant for quantification. The Decision Tree for SSR Selection and Quantification in Annex 5 may be useful.

Due to past practices, the potential for SOC sequestration in many agricultural soil types is high. It is anticipated that sequestration of 0.5 T ha^{-1} or more per year of is likely under an adoption of soil improvement practice. Lesser SOC sequestration differentials are likely to occur when soil improving practices are not so stark, reduced till to no till, for example, however, given larger pools of samples these differences in SOC sequestration may be verifiable.

Sources, other than trucking, are limited to GHG emissions resulting from vehicular and equipment engines as determined by another working group.

The Sources, sinks and reservoirs for quantification are the same for all baseline scenarios.

(a) Justify any SSRs that are excluded from quantification based on their relevance (Columns 4 and 5 of Table 2.4).

Project Proponents must apply the relevance criteria provided in the introduction of this guide for justifying exclusions of SSRs from quantification. Project Proponents may select other relevance criteria from good practice guidance or establish and justify relevance criteria if good practice guidance is not available.

SSRs are not relevant if:

- They are covered by another federal greenhouse gas regulation; protocol?

[2] The Project proponent must demonstrate that the project would not have occurred under the business-as-usual and surplus components of the ‘incremental’ eligibility requirement.

- the reduction is achieved through an incentive included on the List of Climate Change Incentive Measures and is beyond the performance level (tonnes/year) established for the measures on this list;
- they are emissions that are associated with the manufacturing of materials (e.g. steel, concrete, etc.) used to manufacture equipment used in the project or baseline;

they are unchanged between the project and the baseline scenario

As what is being measured in this protocol is the net change in GHG values due to farming practices, not changes in GHG emissions per tonne mile or haul distance to a buyer (which may be beyond the Proponent's control), the combination of slight net change (potentially de minims), and the measurement difficulties may warrant exclusion under this protocol.

2.4.1 Boundaries

Default coefficients or factors have been identified for the following off site agricultural activities:

machinery manufacture
herbicide manufacture
product storage (elevator)
truck transportation
rail transportation

No default coefficients or factors have been identified for pesticide manufacture.

IPCC requires that all off site agricultural contributions be taken into account when assessing and compiling GHG emissions to determine net reductions. However, at a time when soon many different industries, including the transportation and rail may be developing protocols and selling emissions credits, who should have ownership of these off site sources and their potential credits?

For example, if rail transportation GHG emissions for grain transportation were included in farm Project calculations, the improvements currently being made by the rail industry in GHG reductions per tonne mile could conceivably accrue to the farmer.

The rail company as the investor in this new technology may be seeking emission credits for the same GHG reductions. In order to ensure there is no double accounting of credits, it is proposed under this protocol that the basis for distribution of off site farm emission credits be based on the concept of ownership and control.

Improvements in locomotive technology or pesticide/ equipment manufacture that reduce overall GHG emissions would accrue to those industries that initiated that change, rather than the farmer, who is part of the production/transportation infrastructure, but not the owner of the changing technology. These reductions should be apportioned to transportation or manufacturing protocols, or apportioned to agricultural subheadings under the appropriate transportation or manufacturing sector sub-account.

Depending on farm circumstances any of these off farm sources may fail the relevance test due to no change of source emissions as a result in a change to soil improving practices.

2.4.2 De minimis exclusions

De minimis exclusion limits for both sources and sinks should recognize should recognize the relative standard error of the measurement of the major variable under this protocol, which is the measurement of soil carbon. De minimis exclusion limits should not be smaller than the standard error as above, which is 5 or 10 % of the mean. Accordingly under this protocol, elements for assessment will be considered de minimis where the change in SOC equivalents is less than 5% of the change in SOC.

The smallest change that can be measured under the sampling and statistical design of this protocol is 0.5 Tonnes carbon per year, or 1,835 kg CO2 equivalents per year. 5% of this value is 91.75 kg /ha/yr $1.38/ha/yr. Under the National Offset System the de minimis threshold for individual emissions is 0.1% (in the instance of soil organic carbon sequestration 1.8 kg/ha/yr) or 10 tonnes whichever is larger. The first threshold, or limitation in effect, at $15 per tonne requires measurement of elements that contribute 2.8 cents or more per hectare per year. The second would require calculation – estimation of minor CO2 equivalents for elements with value ranges of 4 to 91 kg/ha/yr to determine if the size of the farm or pool leads to values in excess of 10 tonnes. For example, a change in farming practices from CT to ZT on dark brown soils for cropping fuel usage of 48.6 kg/ha/yr (based on GHG Farm estimates), or 243 kg over 5 years means the maximum farm size of this description to allow the use of de minimis thresholds is 42 ha, too small to warrant a program: however this is to some extent missing the intent of de minimis classification. The intent of de minimis classification is to balance 'administrative simplicity with risk'. In relation to the quantification of relatively small amounts of soil organic carbon over comparatively long periods of time, with large inherent variation within the sink, the PA guidelines do not satisfy the intent of the guidance, which is the point the above examples are meant to make.

Further to the point, calculation of the affects of the change to soil improving practices on emission creating elements is a reduction in emissions that would lead to a very minor increase in carbon credits. The farmer or the aggregator should have the option of foregoing these potential credits if they feel the costs of calculation, confirmation and verification would exceed potential payments under the protocol.

Analysis of methane sequestration in cultivated lands, based on the likely range of SOC in cultivated soils and utilizing coefficients provided in the Canadian Economic and Emissions Model for Agriculture (CEEMA 2.0): Technical Documentation indicates that sequestration will be less than 4 kg per hectare over a five year term. This is less than 0.1 % of the anticipated SOC response to a farming practice shift. Accordingly, methane sequestration as a separate entity in cultivated lands should be declared de minimis and excluded from quantification calculations.

This information can be provided in the following table:

Table 2.4b Compare controlled, affected or related baseline and project SSRs1.

Identified SSR	2. Baseline (C,R,A)	3. Project (C,R,A)	4. Include or Exclude from Quantification	5. Justification for Exclusion*
Upstream SSRs during Baseline Operation				

Source or removal from the increase or reduction of emissions from transportation of farm inputs	Controlled	Controlled	Include	
Source or removal from the increase or reduction of emissions from transportation of farm inputs	Related	Related	Exclude	Exclude on the basis of lack of ownership and control. Though total emissions may not be de minimis, th net change in emissions between BAU and Projec will almost certainly be de minimis. In particular in relation to the large uncertainty of identifying comprehensive data sources for emissions (both tonne/km and total km).
Source or removal from the increase or reduction of emissions from equipment manufacture	Related	Related	Exclude	Based on lack of ownership and control, also GHGFarm data, CO_2 equivalent differentials for equipment manufacture are all de minimis at 5%.
Source or removal from the increase or reduction of emissions from pesticide manufacture	Related	Related	Exclude	Exclude on the basis of lack of ownership and control.
Source or removal from the increase or reduction of emissions from herbicide manufacture	Related	Related	Exclude	Exclude on the basis of lack of ownership and control. All de minimis at 5%.
On-site SSRs during Baseline Operation				

Sink from the sequestration of CO_2 from soil improving practices	Controlled	Controlled	Include	
Sink from sequestration of CH4 in soil from natural processes	Controlled	Controlled	Exclude	De minimis for coefficient approach, will be captur with other SOC by measurement approach, but w be indistinguishable from background noise.
Source or removal from onsite operation of farm machinery and vehicle emissions	Controlled	Controlled	Include	
Downstream SSRs during Baseline Operation				
Source or removal of emissions from truck transportation of product	Controlled	Controlled	Include	Exclude controlled trucking operations if changes emissions are de minimis
Source or removal of emissions from truck transportation of product	Related	Related	Exclude	Exclude on the basis of lack of ownership and control.
Source or removal of emissions from rail transportation of product	Related	Related	Exclude	Exclude on the basis of lack of ownership and control.
Source or removal of emissions from storage of product	Related	Related	Exclude	Exclude on the basis of lack of ownership and control.
Source or removal of emissions from affect on market	Related	Related	Exclude	Exclude on the basis of lack of ownership and control.
Other				

* Informative annexes to support rationale and / or justification should be referenced in the table.

Source: Project Proponent or company's name and date

Quantify Project and Baseline SSRs

2.5 Quantification of reductions / removals / reversals of relevant SSRs

Drawing from the information in Section 2.4, this section describes the Project Proponent's methods for measuring or estimating the selected SSRs. This allows the PA to assess whether reduction/removal estimates meet the 'real' and 'quantifiable' eligibility requirements and enables the PA to understand the *scientific method behind SSR calculation and measurement. This information may be provided in Table 2.5a.*

(a) List SSRs in order of their expected quantity of emissions/removals, with the key SSRs listed first. (Column 1 in Table 2.5a)

Project Proponents who have previously determined the relevance of their SSRs for quantification will also have to determine the relative importance of each SSR in order to ascertain if the SSRs should be measured or estimated and if so, how frequently. This requires identifying which SSRs are considered ‘key’ SSRs, which should, at least, be estimated on a frequent basis. The following explains what criteria the PA expects the Project Proponent to evaluate in order to establish key SSRs.

The criteria listed below must be evaluated by Project Proponents when determining which SSRs they are quantifying are ‘key’ SSRs:

- **Mitigation techniques and technologies:** If emissions from a SSR are being reduced significantly through the use of mitigation techniques or technologies, it is good practice to identify these SSRs as key SSRs. This will ensure that they are prioritised within the quantification and that high quality data is collected and maintained.

- **High expected emission growth or reduction/removal potential:** If Project Proponents expect emissions from a SSR to grow significantly in the future they must identify that SSR as a key SSR. Some of these SSRs can also identified by a quantitative Trend Assessment (see Equation 2 of Annex 6). Designating a SSR as key in anticipation of future emission growth or reduction/removal potential is desirable because it can result in earlier use of more accurate data collection techniques and earlier collection of more detailed data. This can reduce the need for future changes in the quantification methodology and simplify the recalculation of the reduction/removal estimates over the time series if changes are needed to the quantification methodology.

- **High uncertainty**: If Project Proponents are not quantifying uncertainty in their reduction/removal calculations, they may want to identify those SSRs that they qualitatively determine as being the most uncertain as key SSRs. Improving the accuracy of the quantification techniques for these SSRs can lead to the largest reduction in overall quantification uncertainty for the project. Identifying these SSRs as key SSRs can lead to improvements in the quantification methodology.

- **Unexpectedly low or high emissions:** As a project progresses, Project Proponents may find SSRs that have an unexpected change in emissions. Project Proponents may want to identify those SSRs that show unexpectedly low or high emission estimates as key SSRs. It is good practice to focus attention on SSRS where unexpected results are observed, to ensure that the results for the quantification methodology are reliable. In addition, Project Proponents can consider implementing special QA/QC if unexpectedly low or high SSRs are designated as key.

In most cases, the application of these qualitative criteria will identify key SSRs that can be identified as key SSRs through similar quantitative analysis. Annex 6 presents some more quantitative approaches to identifying key SSRs.

(a) List the calculation equation and provide a source or justify the selection of the calculation equation. (Row 3 in Table 2.5a)

Project Proponents must provide the calculation equation for each SSR and reference the source, if applicable. Project Proponents should also provide an explanation for why other recognized calculation approaches are not being used for the project. This further justification should be provided as an informative annex.

Projects Receiving Incentives from Areas Covered by the List of Climate Change Incentive Measures

Projects receiving incentives from areas covered by the list of Climate Change Incentive Measures may be prescribed a methodology for determining the number of surplus credits. Only reductions or removals from the projects that are surplus could be considered for Offset System credits. These methodologies for determining performance standards will be posted on our website as they become available (the website will be linked through: www.climatechange.ec.gc.ca).

(a) List the parameters for measurement that apply to each SSR and explain why these parameters were selected (Column 2 of Table 2.5a).

The calculation of emissions/removals from an SSR may involve several parameters. For example, reductions of methane from a landfill gas capture and combustion project would require measurement of the flow of landfill gas, estimation of the destruction efficiency of the combustor and measurement of the concentration of methane in the landfill gas. Parameters for Key SSRs must be considered for continuous or periodic measurement or at least frequent estimation.

(d) List the units of measurement for each parameter (Column 3 of Table 2.5a).

(e) List whether the SSR will be estimated or measured and explain why (Column 4 of Table 2.5a).

Calculating SSRs for the project and baseline can include a broad range of activities that vary from continuous measurement to modelling using broad assumptions. These techniques can be classified under measurement and/or estimation.

(f) Describe methods for estimation or measurement (Column 5 of Table 2.5a).

Methods for measurement or estimation can range from simple counting of a parameter to installation of equipment to continuously measure a parameter. Descriptions of methods must provide enough detail to determine if the parameter is quantifiable. For direct measurement of a parameter, the performance of the equipment must be specified.

Project Proponents will be allowed to use emission/removal factors to quantify the emissions or removals of the project and baseline, provided their use meets the established criteria. The Project Proponent must reference the source of all emission/removal factors used and may choose to develop their own emission/removal factors for their QM.

(g) List the frequency of measurement or estimation for the parameters. More significant parameters should be measured more frequently (Column 6 of Table 2.5a).

The frequency at which a Project Proponent measures or estimates a particular SSR will depend on whether it is a key SSR to the overall calculation of reductions/removals. Section 2.5(a) provides qualitative techniques for identifying key SSRs and Annex 6 provides quantitative approaches to determine which SSRs are key SSRs for quantification.

In general, the PA expects that when emission/reduction/removal levels are large (in terms of quantity) and vary significantly or are difficult to estimate in advance, the SSRs should be considered for continuous measurement or frequent periodic measurement.

(h) Explain how measurement or estimates of the emissions are as accurate as practical for the project and the baseline. Justify any uncertainties that are not quantified and explain the assumptions (Column 7 of Table 2.5a).

Project Proponents must explain how the chosen measurement or estimation method for each identified parameter ensures that calculations of reductions/removals are as accurate as practical. The Project Proponent must explain how the assumptions (i.e. calculations) in the measurement / estimation reduce uncertainty and do not introduce bias.

Methodologies for calculating and aggregating uncertainties exist in many engineering and statistical handbooks. Those used for greenhouse gas inventories are available from the Intergovernmental Panel on Climate Change (IPCC) at: http://www.ipcc-nggip.iges.or.jp/public/gp/english/

The PA expects that uncertainty in measured data and estimates will be quantified using appropriate uncertainty estimation and aggregation techniques. If the Project Proponent decides not to quantify this uncertainty, a justification must be provided.

There is no sited monitoring apparatus in the field. Samples will be collected during field inspections. Sample analysis will be completed in the lab.

Monitoring consists of two parts:

- Records — The independent verification of farming practices, in conjunction with the compilation of farm records (financial, legal, contractual and anecdotal) is necessary to substantiate that farming practices meet and maintain Project eligibility requirements

- Examples of farm records:
  - crop inputs
  - fuel records
  - yields- grain and straw
  - straw management
  - herbicide field application reports
  - third party confirmation of farming practices for controls
  - product shipping expense receipts

- Sampling SOC — The scientific design, sampling and determination of

  Carbon by field measurement.

- Examples
  - procedures
  - sampling records
  - statistics
  - mapping
  - analytical reports

Records will be will be submitted to the PA, at the application stage and annually with third party verification during the term of the Project.

Sampling data, including field notes, sample records, lab results and analysis will be submitted to the PA, upon approval of the Project and every fifth year thereafter for a term of 25 years.

All data submitted to meet and maintain eligibility under a Project must be certifiable. Due to the large costs associated with custom baselines and reporting of annual measured emissions results, and the large land base required to ameliorate costs; it is anticipated that individuals will apply under the measurement scenario as part of a group. It is anticipated that each group or pool will be managed by an aggregator. The aggregator, will be required to provide the following services:

- signup potential Participants for the Project
- Collect, review and collate each Participants records as identified above to ensure accuracy, completeness and consistency, for the determination of all sources (identified by the PA in this protocol) and practices for each participant.
- Monitor SOC for the Project, including analysis of lab results for the purposes of reporting to the PA
- For “projects” with practice changes dates prior to project validation/registration, use procedures identified under this protocol, back-calculate baseline soil organic carbon (by modelling),
- Create an average baseline, or individual baselines, for the “project” for the purposes of reporting to the “project” Authority.
- Assess and map all soil types to determine for the purposes of reporting the net area of all Project fields that meet eligibility requirements according to the soil/ practices matrix provided in the protocol.
- Inspect and confirm management practices on an annual basis, this may not be required for most measured Projects.
- Review and report the findings of the specialist to the PA.
- Enter into a contract with a licensed P. Ag. Certifier to review and assess field practices and aggregator submissions to the PA.

It is the role of the certifier to provide validation and transparency of the completion of all activities undertaken by all participants under this protocol. Certifier responsibilities consist of:

- Inspection and confirmation of farming practices.
- Inspection and confirmation of stratification of farm field areas that meet the soil/ practices matrix provided in the Protocol.

- Review of records data as supplied to PA for the Project to ensure there is no material misstatement of fact.
- Review of initial, annual and final records data and submissions to ensure completeness, consistency and accuracy.
- Review of aggregator participant records and confirm calculations related to baselines.
- Review of specialist methodology, mapping, records and reports- including lab reports- and analysis to confirm accuracy and consistency.
- Preparation of a report that quantifies all discrepancies noted during the review.

2.5.1 Monitoring data quality management

Standards and rules (This section must be consistent with verification procedures under Canadian Domestic Offset System).

- To ensure fair play and consistency of standards the following guidelines should be applied.
- No conflict of interest:
- No aggregator, or certifier may play more than one of these roles for the same Project within a five year period.
- No misstatement of material fact. A material misstatement of fact would be grounds for rejection of the Project application or suspension of approval until the misstatement is corrected.
- Certifiers, during their review process will evaluate uncertainties and concentrate their efforts where uncertainties will have the greatest impact on net sources, sinks and reservoirs.
- The maximum discrepancy between Aggregator and certifier quantifications will be 5% or within 95% of confidence limits, whichever is larger.
- The question is - is this proposed regulatory framework sufficient to meet Canadian and IPCC requirements and is it affordable for all Participants?

Table 2.5a Procedures for Measuring/Estimating Parameters for Calculating SSRs for each GHG.

1. Project / Baseline SSR (list key SSRs first)	**2. Parameter / Variable**	**3. Unit**	**4. Measured / Estimated**	**5. Method**	**6. Frequency**	**7. Justify measurement or estimation and frequency**
			GHG CO_2			
SSR #1	**Calculation Equation**					
Soil organic carbon	Parameter #1 Organic Carbon	T/ha CO_2e	measured	Multiple site sampling	At start and end of crediting	The minimum anticipated period is 5 years

					period.	
SSR #2	**Calculation Equation**					
Net emissions or removals from machinery operation onsite	Parameter #1 Fuel to energy to CO_2e	Litres/ha converted to gigajoules/ha converted to CO_2e in T or kg/ha based on farming practice	measured or estimated	assessed from farm records or applicable coefficients	annually	Based on records of fuel purchase or application of coefficients.
SSR #3	**Calculation Equation**					
Net emissions or removals from offsite transportation of product	Parameter #1 Fuel to energy to CO_2e	Litres/ha converted to gigajoules/ha converted to CO_2e in T or kg/ha	measured	assessed from farm records	annually	Based on records of fuel purchase.
SSR#4	**Calculation Equation**					
Net emissions or removals from offsite transportation of farm inputs	Parameter #1 Fuel to energy to CO_2e	Litres/ha converted to gigajoules/ha converted to CO_2e in T or kg/ha	measured	assessed from farm records	annually	Based on records of fuel purchase. This SSR should be considered de minimis if no farm records available.

* Provide source of equation or informative annexes to support rationale and / or justification

Source: Project Proponent or company's name and date

(i) Describe contingency measures to ensure continuous data collection for each parameter (Column 5 in Table 2.5b).

There may be situations during the operation of a project when data cannot be collected through the established methods. To ensure that data collection is maintained for the duration of the registration period, the Project Proponent should describe the contingency procedures for monitoring the project or baseline data. Contingency measures for maintaining data quality are especially important for key SSRs.

This information can be provided in the following table:

Table 2.5b Contingency Procedures for Measuring/Estimating Parameters for Calculating Relevant SSRs.

1. Project / Baseline SSR (List key SSRs first)	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Contingency Method	6. Frequency	7. Justify measurement estimation a[nd] frequency
SSR #1	**Calculation Equation**					

Soil organic carbon	Parameter #1 Organic Carbon	T/ha CO_2e	Measured	Surplus sites sampled and stored to be used if needed.	20% Surplus	Estimate <20% loss of sites. Co inhibits more sampling.
SSR #2	**Calculation Equation**					
Net emissions or removals from machinery operation onsite	Parameter #1 Fuel to energy to CO_2e	Litres/ha converted to gigajoules/ha converted to CO_2e in T or kg/ha based on farming practice	Estimated	Applicable coefficient	Annually	Apply coefficien
SSR #3	**Calculation Equation**					
Net emissions or removals from offsite transportation of product	Parameter #1 Fuel to energy to CO_2e	Litres/ha converted to gigajoules/ha converted to CO_2e in T or kg/ha	Exclude or same as previous year	NA	NA	Exclude or sam as last year determined
SSR#4	**Calculation Equation**					
Net emissions or removals from offsite transportation of farm inputs	Parameter #1 Fuel to energy to CO_2e	Litres/ha converted to gigajoules/ha converted to CO_2e in T or kg/ha	Exclude or same as previous year	NA	NA	Exclude or sam as last year determined

* Informative annexes to support rationale and / or justification should be referenced in the table.
Source: Project Proponent or company's name and date

For Sink Projects:

A sink project will increase the carbon in a reservoir relative to the baseline. There are two quantification methods for these projects:

• **Stock method:** The Proponent **quantifies the level of carbon** in the reservoir from both the project and the baseline at the end of a given period.

• **Flow (or Rate) method:** The Project Proponent **quantifies the carbon stock change** for a given period for all the sinks and sources that are associated with the reservoir.

- Sink projects that are applying for both offset credits and temporary credits must quantify their emission removals separately for each area.
- For sink projects that are issued temporary credits, if the Reduction/Removal Report covers a crediting period of more than one year, the Project Proponent must specify a methodology for interpolating the carbon stock changes for the baseline and project for each year of the crediting duration. This is required to differentiate between the number of

incremental tonnes maintained and the number of new incremental tonnes sequestered for a given year.

Quantification of reversals

Climate change could affect SOC levels and sequestration rates. This is beyond the control of the producer. If losses occur it is expected that they would be less than without the soil improving practice.

As long as soil improving practices are maintained, no reversal of soil organic carbon gains are likely to occur. Should a Project farm or pool revert to conventional practices, or establish new practices under a quantification protocol, the confirmation of the impact of the latter change in practices would have to be measured, or estimated with Models or coefficients, by the verifier to either ensure the stored carbon is intact, or there are grounds for legal action to recoup the loss. The cost of measurement may initially have to be born by the verifier, and in the event of demonstrable loss, recovered from the Proponent.

There should be a clause in the agreement that if practices change, re-measurement will be required at the end of the liability period, at the Proponent’s expense, unless the expert consensus is that SOC will be maintained or increased under the new practices. In order for these losses to be quantified it is assumed that these losses would have to approximate the minimum measurable gain under the protocol.

Describe the relevant reservoirs for the baseline and the project that will be monitored to ensure that reversals of removals are quantified.

Sink projects that have been issued offset credits, require long-term monitoring to ensure that the requirements associated with the permanency of the removals are met. The Project Proponent must quantify possible reversals of carbon, and justify which reservoirs will be monitored during the liability period. The Project Proponent must select these reservoirs on the basis of the longevity of the reservoir and the stability of its stocks given the management and disturbance environment in which the reservoir occurs.

The reservoir that will be monitored is farm soil. Monitoring will consist of inspections of fields or satellite imagery to ensure that soil improving practices are continued. There will be no soil measurement unless such practices are discontinued in which case SOC would be measured at the end of the liability period.

Verification of results

The complete and precise information provided in this section is critical for successful verification.

Using the information provided in Section 3.1, the verifiers will:

- Verify that the reduction/removal report is a fair and accurate representation of reductions or removals achieved during the reporting period;
- Verify that the reductions were achieved in accordance with the approved quantification methodology or protocol;
- Verify that the project was implemented in accordance with the required sections of the registered Project Document.

A strategy that provides for the verification of the technical parts of this quantification protocol will at a minimum address the following procedures and factors:

- Sample collection locations will be assessed to ensure non-bias of sample locations.
- Written sampling procedures will be reviewed to ensure that samples delivered to labs for analysis will arrive in an unmodified state.
- Verification should be built into the Project proposal in the form of a fixed proportion of blind sample collection and testing, consistent with the standards of the North American Proficiency Testing Program. The methods to collect, test and the results of the required blind tests will be reviewed.
- Selected statistical calculations will be re-run to confirm mathematical accuracy and outcomes reviewed as to the validity of confidence limits and statistical significance.
- Where receipts are used, financial auditing techniques will be used to substantiate fuel usage, and selected calculations of CO_2 equivalents will be rerun to confirm mathematical accuracy.
- Spot checks on a small percentage of fields as part of a larger review of Projects will assessed in the spring of each year to confirm practices.

Describe the relevant reservoirs for the baseline and the project that will be monitored to ensure that reversals of removals are quantified.

Sink projects that have been issued offset credits, require long-term monitoring to ensure that the requirements associated with the permanency of the removals are met. The Project Proponent must quantify possible reversals of carbon, and justify which reservoirs will be monitored during the liability period. The Project Proponent must select these reservoirs on the basis of the longevity of the reservoir and the stability of its stocks given the management and disturbance environment in which the reservoir occurs.

Monitoring and Data Quality

2.6 Management of Data Quality

The information provided in this section will indicate the appropriate monitoring and quality control procedures for each SSR and will assess if the 'verifiable' eligibility requirement is being met. This will assure the PA that there are appropriate controls for management of data quality and record keeping.

Describe data quality management and contingency procedures

For the SSRs listed in Section 2.5, describe how data quality will be maintained for the duration of the project. Explain how measurement or estimation contingency procedures for managing data quality from the project or baseline data will ensure that verifiable data will be maintained by the Project Proponent. These can include, for example, data logging and backup procedures, and authority for sign-off on data quality.

Guidance on data quality management can be obtained from various sources, including the Intergovernmental Panel on Climate Change (http://www.ipcc-nggip.iges.or.jp/public/gp/english/8_QA-QC.pdf), and the Organization for Economic Cooperation and Development guidance on Good Laboratory Practice (http://www.oecd.org/about/0,2337,en_2649_34381_1_1_1_1_1,00.html)

This information can be provided in the following table:

2.7 SSR parameters, data management and contingency procedure.

Relevant SSRs	Parameters	Data Quality Management Procedure	Explanation for how Procedures meet 'Verifiable' requirement
Soil organic carbon	Parameter #1 Organic Carbon	Field assessments and lab analysis will be audited by verifier	Results will be statistically sound and verified.
Net emissions or removals from machinery	Parameter #1 Fuel to energy to CO_2e	Farm records used as a measurement basis are anticipated to be the	Conversions are based on accepted coefficients/ factors.

operation onsite		same as those used for tax purposes as an expense, so there is little risk of minimizing these values	
Net emissions or removals from offsite transportation of product	Parameter #1 Fuel to energy to CO_2e	Farm records used as a measurement basis are anticipated to be the same as those used for tax purposes as an expense, so there is little risk of minimizing these values. Results among individual farms will be compared and any outlines will be checked and explained.	Conversions are based on accepted coefficients/ factors.
Net emissions or removals from offsite transportation of farm inputs	Parameter #1 Fuel to energy to CO_2e	Farm records used as a measurement basis are anticipated to be the same as those used for tax purposes as an expense, so there is little risk of minimizing these values	Conversions are based on accepted coefficients/ factors.

* Informative annexes to support rationale and / or justification should be referenced in the table.
Source: Project Proponent or company's name and date

A quality assurance and quality control plan must be submitted as part of the Project proposal, however quality assurance and control should be apparent throughout all components of the Project. Quality assurance and control should be demonstrated in the Project proposal as a comprehensive system of checks, confirmations or corrections, documentation and review and verification procedures. The quality assurance and quality control plan for the proposed Project should include all of these processes in detailed terms as well as documentation processes and archiving procedures.

Concern: Should we provide recommendations regarding legal advice for contracts, etc. to all participants?

Annex 13 Project Examples

For offsite examples need NCGAVS coefficients or factors for CO_2 emissions per gigajoules or how to apply GHGFarm coefficient

Farm 1 Conventional Till to Zero Till

ASSESSMENT ELEMENT	COMMENTS	VALUES PER HECTARE	SUBTOTAL TONNES CO2 PER HECTARE
CH4 SEQUESTRATION AS CARBON IN SOIL	de minimis no calculation		
MEASURED CARBON YEAR 0 (start of year 1)	measured tonnes C per hectare	20	
MEASURED CARBON YEAR 5	measured tonnes C per hectare	22.5	
NET SOIL GAIN	tonnes C per hectare	2.5	
CO2 EQUIVALENTS	3.666666	3.67	9.175
CT FUEL USE YEAR O X THOUSAND LITRES (from fuel records for all farms and converted to gigajoules - use of coefficients still required) conversion also required to convert gigajoules per hectare to kg CO2 per ha	2.02 gigajoules at 76.28 kg CO2 per gigajoule per hectare	154.0856	
ZT FUEL USE YEAR 5	1.42 gigajoules at 71.35 kg CO2 per gigajoule per hectare,	101.317	
REDUCED DIRECT FUEL CONSUMPTION	(kg) per hectare	52.7686	
REDUCED DIRECT FUEL CONSUMPTION FOR FIVE YEARS	(kg) per hectare	263.843	0.263843
NET SEQUESTRATION FOR FARM PER HECTARE	tonnes CO2 per hectare		9.439
NET SEQUESTRATION CO2 FOR FARM	tonnes on 500 ha	500	4719
Farm where change in practices from reduced till to no till occurs on brown soils for the full term of the project, soil organic carbon was measured prior to change in treatment, and at the end of the project, fuel consumption was identified from receipts or tax return information.			
Note: coefficients are still required to estimate CO2 emissions based on estimates of the proportion of different activities.			

Farm 2 Reduced Till to Zero Till

ROW NUMBER	ASSESSMENT ITEM	COMMENTS	VALUES PER HECTARE	SUBTOTAL TONNES CO2 PER HECTARE
1	CH4 SEQUESTRATION AS CARBON IN SOIL	de minimis no calculation		
2	MEASURED CARBON YEAR 0 (start of year 1)	measured tonnes C per hectare	20	
3	MEASURED CARBON YEAR 5	measured tonnes C per hectare	21.3	
4	NET SOIL GAIN)	tonnes C per hectare	1.3	
7	CO2 EQUIVALENTS	(3.666666)	3.67	4.771
8	CT FUEL USE YEAR O X THOUSAND LITRES (from fuel records for all farms and converted to gigajoules - use of coefficients still required) conversion also required to convert gigajoules per hectare to kg CO2 per ha	2.02 gigajoules at 76.28 kg CO2 per gigajoule per hectare	154.0856	
9	ZT FUEL USE YEAR 5	1.42 gigajoules at 71.35 kg CO2 per gigajoule per hectare, 1.12 gigajoules 'estimate' for perennial cropping due to no seeding	101.317	
10	REDUCED DIRECT FUEL CONSUMPTION	(kg) per hectare	52.7686	
11	REDUCED DIRECT FUEL CONSUMPTION FOR FIVE YEARS	(kg) per hectare	263.843	0.263843
12	NET SEQUESTRATION per ha FOR FARM OVER 5 YEARS	tonnes CO2 per hectare		5.035
13	NET SEQUESTRATION FOR FARM OVER 5 YEARS (TONNES)	tonnes on 500 ha		2517

Farm where change in practices from reduced till to no till occurs on brown soils for the full term of the project, soil organic carbon was measured prior to change in treatment, and at the end of the project, fuel consumption was identified from receipts or tax return information.

Note: coefficients are still required to estimate CO2 emissions based on estimates of the proportion of different activities.

Annex 15 References

Agriculture, Food and Rural Development. 2003. Development of a farm-level greenhouse gas assessment: identification of knowledge gaps and development of a science plan. University of Alberta.

Alder, V. and Charlton, D.1997. Development of standard methodologies for resident biomass and organic carbon. Research Branch, Agriculture and Agri-Food Canada.

Angers, D.A., Bolinder, M.A., Carter, M.R., Gregorich, E.G., Drury, C.F., Liang, B.C., Voroney, R.P., Simard, R.R., Donals, R.G., Beyaert, R.P. and Martel, J. 1997. Impact of tillage practices on organic carbon and nitrogen storage in cool, humid soils of eastern Canada. Soil and Tillage Research. 41:191-201.

Bates, T.E. 1993. Soil handling and preparation. Pp. 19-24. In: M.R. Carter (Ed). Soil sampling and methods of analysis. Lewis Publishers.

Bergstrom, D.W., Monreal, C.M., and St. Jacques, E. 2001a. Spatial dependence of soil organic carbon mass and its relationship to soil series and topography. Can. J. Soil. Sci. 81: 53-62.

Bergstrom, D.W., Monreal, C.M., and St. Jacques, E. 2001b. Influence of tillage practice on carbon sequestration is scale-dependent. Can. J. Soil. Sci. 81: 63-70.

Bergstrom, D.W. Point measurement of soil carbon storage. Manuscript.

Bisutti, I., Hilke, I., and Raessler, M. 2004. Determination of total organic carbon – an overview of current methods. Trends in Analytical Chemistry. 23: 716-726.

Boehm, M. and B McConkey. 2002. Agricultural soil sink potential in Saskatchewan. Agriculture and Agrifood Canada.

Bricklemyer, R.S., R.L. Lawrence and Miller, R.R. 2002. Documenting no-till and conventional till practices using Landsat ETM+ imagery and logistic regression. J. Soil Wat. Cons. 57: 267-271.

Bricklemyer, R.S., Miller, P.R., Paustian, K., Keck, T., Nielsen, G.A., and Antle, J.M. 2005. Soil organic carbon variability and sampling optimization in Montana dryland wheat fields. Soil and Water Conservation Society. 60:42-51.

California Energy Commission. 2002. Guidance to the California climate action registry.

Campbell, C.A., Zetner, R.P., Selles, F., Biederbeck, V.O., McConkey, B.G., Blomert, B., and Jfferson, P.G. 2000a. Quantifying short-term effects of crop rotations on soil organic carbon in southwestern Saskatchewan. Can. J. Soil Sci. 80:193-202.

Campbell, C.A., Zetner, R.P., Liang, B.C., Roloff, G., Gregorich, E.C., and Blomert, B. 2000b. Organic C accumulation in soil over 30 years in semiarid southwestern Saskatechwan – effect of crop rotations and fertilizers. Can. J. Soil Sci. 80:179-192.

Campbell, C.A., McConkey, B.G., Zetner, R.P., Selles, F., and Curtin, D. 1996. Tillage and crop rotation effects on soil organic C and N in a coarse-textured Typic Haploboroll in southwestern Saskatchewan. Soil and Tillage Research. 37:3-14.

Cannon, K.R. 2002. Alberta benchmark site selection and sampling protocols. AESA.

Carter, M.R., Angers, D.A., Gregorich, E.G., and Bolinder, M.A. 1997. Organic carbon and nitrogen stocks and storage profiles in cool, humid soils of eastern Canada. Can. J. Soil. Sci. 77: 205-210.

Conant, R.T., Smith, R., and Paustian, K. 2003. Spatial variability of soil carbon in forested and cultivated sites: implications for change detection. J. Environ. Quail. 32:278-286.

Conant, R.T. and Paustian, K. 2002. Spatial variability of soil organic carbon in grasslands: implications for detecting change at different scales. Environmental Pollution. 116:S127-S135.

Ellert, B.H. and Bettany, J.R. 1995. Calculation of organic matter and nutrients stored in soils under contrasting management regimes. Can. J. Soil Sci. 75:529-538.

Ellert, B.H, Janzen, H.H., and Entz, T. 2002. Assessment of a method to measure temporal change in soil carbon storage. Soil. Sci. Soc. Am. J. 66: 1687-1695.

Environment Canada. 2006. Developing an offset system quantification protocol or methodology.

Hartman, M. Direct seeding: estimating the value of crop residues. Alberta Agriculture, Food and Rural Development. Available: www.agric.gov.ab.ca$department/deptdocs.nsf/all/agdex2512

Hastie, J. 2002. Reduction and removal of agricultural greenhouse gas emissions in Alberta soil measuring, monitoring and verification land use database and benchmark field plan. Climate Change Central.

Helgason, B. 2005. GHGFarm An assessment tool for estimating net greenhouse gas emissions from Canadian farms. Unpublished draft

Intergovernmental Panel on Climate Change.1997. Revised 1996 IPCC guidelines for national greenhouse gas inventories: Reporting Instructions Annex 1 A 1.2pg 1.4-1.6.

Intergovernmental Panel on Climate Change.1997. Revised 1996 IPCC guidelines for national greenhouse gas inventories: Workbook 4.32-41, 5.31-5.33.

Intergovernmental Panel on Climate Change. 2001. IPCC good practice guidance and uncertainty management in national greenhouse gas inventories: Chapter 8. Quality Assurance and Quality Control, Annex 1, Conceptual Basis for Uncertainty Analysis.

Izaurralde, R.C., McGill, W.B., Robertson, J.A., Juma, N.G., and Thurston, J. 2001. Carbon balance of the Breton Classical Plots over half a century. Soil. Sci. Soc. Am. J. 65: 431-441.

Jones, L. 2006. A guide to verification under the Canadian offset system (draft

Johnston, M. 2002. The carbon sink potential in Saskatchewan.

Kachanoski, G. 1996. Development of standard methodologies: resident biomass and organic carbon. Research Branch, Agriculture and Agri-Food Canada.

McConkey, B., B. Chang Liang, G. Padbury and Lindwall, W. 2005. Carbon sequestration and direct seeding. Saskatchewan Soil Conservation Association.

McKenzie, N., P. Ryan, P. Fogarty and Wood, J. 2000. Sampling, measurement and analytical protocols for carbon estimation in soil, litter and coarse woody debris. Technical Report no. 14. Australian Greenhouse Office.

Monreal, C.M., Etchevers, J.D., Acosta, M., Hidalgo, C., Padilla, J., Lopez, R.M., Jimenez, L., and Velazquez, A. 2005. A method for measuring above and below ground C stocks in hillside landscapes. Can. J. Soil. Sci. 85: 523-530.

National Environmental Protection Council.1999. Guideline on laboratory analysis of potentially contaminated soils. National Environmental Protection Council Service Corporation. Adelaide, Australia.

Nebraska Department of Natural Resources. 2001. Carbon sequestration, greenhouse gas emissions, and Nebraska agriculture – background and potential. Nebraska Department of Natural Resources.

Nelson, D.W. and Sommers, L.E. 1996. Carbon and organic matter. Pp. 961-1010. In: J.M. Bartels (Ed). Methods of soil analysis: part 3 chemical methods. Soil Science Society of America.

Pendell, D.L., J.R. Williams, C.W. Rice, and Nelson, R.G. S.B. Boyles. An economic feasibility analysis of manure applications and no-tillage for soil carbon sequestration in corn production. Presented at: Third USDA Symposium on Greenhouse Gases and Carbon Sequestration in Agriculture and Forestry. March 21-24, 2005.

Plante, A.F. Stewart, C.E., Conant, R.T., Paustian, K. and Six, J. 2006. Soil management effects on organic carbon in isolated fractions of a Gray Luvisol. Can. J. Soil Sci. 86:141-151.

Post, W.M., Izaurralde, R.C., Mann, L.K., and Bliss, N. 2001. Monitoring and verifying changes of organic carbon in soil. Climatic Change. 51: 73-99.

Rice, C. 1994. Carbon sequestration policy: providing science-based information presentation. CASMGS.

Sheldrick, B.H. and Wang, C. 1993. Particle size distribution. Pp. 499-512. In: M.R. Carter (Ed). Soil sampling and methods of analysis. Lewis Publishers.

Snowdon, P., J. Raison, H. Keith, P. Rison, P. Grierson, M. Adams, K. Montagu, H. Bi, W. Burrows, and Eamus, D. 2002. Protocol for sampling, tree and stand biomass. Technical Report no. 31. Australian Greenhouse Office.

Soon, Y.K. and Abboud, S. 1991. A comparison of some methods for soil organic carbon determination. Commun. Soil. Sci. Plant Anal. 22: 943-954.

Tiessen, H. and Moir, J.O. 1993. Total and organic carbon. Pp. 187-199. In: M.R. Carter (Ed). Soil sampling and methods of analysis. Lewis Publishers.

Tweeten, L. B. Sohngen and Hopkins, J. 1998 Assessing the economics of carbon sequestration in agriculture. Presented at: Workshop on CO_2 Sequestration Schemes and Markets for Carbon Trading in US and Agricultural Sectors

UNFCCC. 2003. Possible ways to establish a level of insignificance at which no adjustments would be required (unedited version). Second Workshop On Adjustments Under Article 5.2 Of The Kyoto Protocol. Lisbon.

VandenBygaart, A.J. and Kay. B.D. 2004. Persistence of soil organic carbon after plowing a long-term no-till field in southern Ontario, Canada. Soil. Sci. Soc. Am. J. 68: 1394-1402.

VandenBygaart, A.J., Gregorich, E.G., Angers, D.A., and McConkey, B.G. 2006. Monitoring soil organic carbon stock changes: assessment of variability in Canadian microsites. In press.

VandenBygaart, A.J. 2006. Monitoring soil organic carbon stock changes in agricultural landscapes: issues and a proposed approach. In press.

Watson, S. Economic nalysis of carbon sequestration in continuous corn. www.casmgs.colostate.edu/insider/vigview.asp?action=titleid=453

West, T.O. and Post, W.M. 2002. Soil organic carbon sequestration rates by tillage and crop rotation: a global analysis. Soil Sci. Soc. Am. J. 66:1930-1946.

Wilding, L.P., Drees, L.R. and Nordt, L.C. 2001. Spatial variability: Enhancing the mean estimate of organic and inorganic carbon in a sampling unit. Pp. 69-86. In: R. Lal (Ed). Assessment methods for soil carbon. Lewis Publishers

Yang, X.M. and Kay, B.D. 2001. Impacts of tillage practices on total, loose and occluded particulate, and humified organic carbon fractions in soils within a field in southern Ontario. Can. J. Soil. Sci. 81: 149-156.

Yeomans, J.C., and Bremner, J.M. 1988. A rapid and precise method for routine determination of organic carbon in soil. Commun. Soil Sci. Plant Anal. 19: 1467-1476.

Zar, J.H. 1984. Biostatistical Analysis 2nd Ed. Prentice-Hall Canada Inc. Toronto.