Tillage System Default Coefficient Protocol

Deleted: based on
Canada's Offset System for Greenhouse Gases
Technical Background Document, 2005

prepared by

Soil Management Technical Working Group

Principal Author

Deleted: for Canada's GHG Offset System

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October, 2006

Important Note: At the time of completion of this report in October 2006, the status of Canada's Offset System for Greenhouse Gases and its design was uncertain. Therefore, this protocol may have limited applicability.

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Important Caveat: This is a historical document; the scope of the proposed federal GHG offset system has not been finalized. This protocol was not approved by the federal government and may not reflect current federal policy decision.

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Introduction

The Tillage System Default Coefficient Protocol (referred to as the Tillage Protocol in this document) quantifies greenhouse gas (GHG) emission offsets associated with a change from conventional or full tillage (FT) to reduced till (RT) or no-till (NT) in Canadian agricultural soils.

It has long been recognized that Canadian agricultural soils represent a large potential sink for GHG emission removals, and that the practices of no-till (or zero till) and reduced till (or minimum till) are key practices to achieve this goal. Discussion on how agricultural soils and these practices can participate in an Offset System have been underway for a number of years. The Soil Management Technical Working Group (SMTWG) was directed to develop this protocol. In this protocol the SMTWG has provided rationale for all decisions made, and has also attempted to provide clearer rationale for the previous guidance provided in the Technical Background Document.

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Deleted: and the federal government already developed a number of policy guidelines that were incorporated into the initial Offset System design. Some of these design elements, as described in the Offset System Technical Background Document (TBD), are listed below.¶
¶
[192] To facilitate the participation of agriculture sink projects in the Offset System, the Government of Canada, in collaboration with provinces/territories, is developing a quantification protocol for soil sinks. Proponents will have the option to choose between using the default quantification protocol, or could develop a customized methodology as described in the next section.¶
¶
[193] The quantification protocol will use removal factors to quantify carbon stock changes. Project Proponents that choose to use the protocol will multiply the verified number of hectares over which the practice has been implemented by the removal factor in the protocol. If there is a change in practice that could result in the release of carbon removed, the Proponent will calculate the reversal using a reversal factor set out in the protocol.¶
¶
[194] The default approach will be designed to achieve accuracy at the aggregate level. Removal factors will require adjustment on an on-going basis to ensure the accuracy of the factors are maintained. For example, an adjustment will be required if additional Project Proponents join the group using the default approach or if Project Proponents leave the group to use a customized approach. Adjustments to the removal factors will not affect the credits already issued.¶
¶
[195] The default approach will not require Project Proponents to provide historical infor ... [1]

Section I Protocol Scope and Description

Describe the Project

1.1 Scope and Description

1.1 (a) Protocol scope, activities and objectives

The tillage protocol quantifies GHG emission reductions and removals for the practices of no-till and reduced till. It uses the same coefficients utilized by the National Carbon and Greenhouse Gas Accounting and Verification System (NCGAVS) in Canada's inventory reporting requirements for the Kyoto protocol. This protocol is considered a "default", as opposed to a "customized" methodology because it can be applied to all land and all agricultural producers across the country regardless of the historical practices associated with the land or a producer.

In order to make the default approach feasible and credible it is necessary to create project coefficients and baseline deductions that are regionally aggregated. In other words in a given region all project lands doing no-till receive the same emission factor per area regardless of what tillage systems were used in the past. As such this protocol strives to simplify and minimize project administrative costs by not having to collect and analyze historical information for project land parcels.

With any coefficient based protocol, there is a requirement for clearly stated activity definitions. The practices of no-till and reduced till are no exception. There has always been a variety of terms used in the agricultural industry to describe these practices (eg. also zero till, minimum till, direct seeding, and low disturbance direct seeding), with somewhat different interpretations regarding the specific meaning of these terms. It is critical that the activity definitions used in this protocol are consistent for all components of the protocol, as listed below:

- Must be consistent with definitions used to generate all emission factors including soil carbon sequestration, N_2O reductions, and energy consumption reductions.
- Must be consistent with tillage adoption data used for baseline scenario analysis.
- Must be practical and clearly understood by producers, and must contain a reasonable degree of flexibility to enable effective implementation within complex farming systems.
- Must be verifiable through monitoring and verification processes.

Another key issue with this protocol is the concept of regionalization. All components of the protocol involve regional differences across the country. This includes emission factors, activity definitions, tillage adoption data for baseline scenario analysis, and monitoring / verification processes. However, because this protocol uses a default approach it is appropriate that the number of regions is relatively small, and consistent for all of the above components.

This "default" protocol has always been envisioned as one of several options for projects involving the practices of no-till and reduced till. Other "customized" options could also be developed as projects or protocols, and these could involve customized coefficients suitable for more local areas or using a measurement approach to quantify soil carbon change.

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The SMTWG recognizes that there are other soil management practices that also contribute to increased soil carbon, which could also be considered in a GHG emission removal project. It is not the intent of this protocol to exclude other practices, but rather address one of the primary practices as a first step. Additional "default" protocols should be developed for practices such as fallow reduction and perennial forages in rotation with annual crops. It is envisioned that many producers would desire to bundle these protocols into a single project in order to increase efficiencies and add value. For example, additional practices in a project would result in incrementally lower monitoring and verification costs, since a significant portion of the same data is required for monitoring all practices (eg. land locations, parcel size).

This protocol is applicable to annual crops grown throughout Canada. Perennial crops are not within the scope of this protocol. While some perennial row crops may involve tillage (eg. orchards, small fruits, nuts, nurseries, woodlots, etc), the coefficients used in this protocol are not applicable since tillage in these scenarios only involves part of the land area (ie. the inter row zone). The impact of including perennial crops in rotation with annual crops is addressed in section 3.2 (b).

1.1 (b) Evidence required to demonstrate a project is within the scope of the protocol

Project proposals must demonstrate adherence or compliance with all of the following key ingredients of the protocol.

- Apply the emission factors provided for implementation of no-till and reduced till
- Apply the reversal emission factors provided for changing from no-till to full till, or reduced till to full till
- Adhere to the specific activity definitions provided for no-till, reduced till, and full till.
- Respect the regional variation of emission factors and activity definitions by applying the correct factors and definitions to specific land parcels according to the region where they are located
- Maintain accurate and verifiable records of legal locations, size and location of project areas within legal location parcels, specific tillage activity data for all lands included in the project through both the crediting and liability period
- Ensure that all project lands are located within Canada
- Ensure that no additional emission reduction credits are being claimed for the practices of no-till and reduced till on these same lands through another project or initiative during the same time period
- Ensure that no additional emission reduction credits are being claimed for on project land areas during the same time period for any other practices that achieve their credits through soil carbon sequestration. The only exception to this is a future standardized protocol for other practices that use the same default approach and therefore can be fully integrated with this protocol.

1.1 (c) Flexibility provisions that the protocol offers

By its very nature a default protocol offers virtually no flexibility, in order to maintain its simplicity, low administrative cost, and wide applicability. At the same time it is recognized that the practices of no-till and reduced till are part of complex cropping and farming systems. These systems are implemented by agricultural producers on diverse soils, landscapes, and climates across Canada. Therefore, it is imperative that the specific activity definitions used in this protocol provide enough flexibility to agricultural producers so that the practices of no-till and reduced till can be feasibly and sustainably implemented under typical management scenarios. At the same time there are reasonable boundaries placed on this flexibility to ensure that the intended objectives to achieve real gains in soil carbon and GHG reductions consistent with the coefficients being used are realized.

1.2 Quantification Protocol Development Approach and Workplan

1.2 (a) QP Development approach

Canada has been a world leader in researching the impact of improved management practices on soil carbon sequestration of agricultural soils. This research was initially motivated by the need to investigate and document improved soil productivity benefits. With the onset of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, much of the motivation for research has been to generate accurate national estimates of GHG emissions and removals as part of Canada's international GHG inventory reporting requirement. These estimates are part of the National Carbon and Greenhouse Gas Accounting and Verification System (NCGAVS) led by Agriculture and Agri-Food Canada (AAFC). Thus this research was broadened to consider other GHG impacts such as nitrous oxide (N_2O).

NCGAVS uses the Century 4.0 model of soil organic carbon (SOC) dynamics to estimate soil carbon change from changing practices (Source: McConkey and others, 2006). Extensive research data from Canada and other countries has been used to validate the model and make improvements over time. The various tillage system definitions used in this protocol are inputted into the model, and soil carbon emission removal coefficients are outputted.

The practices of no-till and reduced till also provide smaller but significant reductions associated with lower N_2O emissions and energy consumption. The NCGAVS utilizes expert interpretation of data to derive these factors (Source: Rochette, Worth, and others, 2005; and Helgason, Smith, and others, 2005).

The NCGAVS is the preferred methodology for quantification for this protocol for the following reasons:

- Provides coefficients for all agricultural regions of Canada where tillage practices are implemented
- Is based on the most up to date scientific knowledge available regarding the impact of tillage practices on GHG emissions and removals
- Provides regional aggregation at a similar scale that is desirable for this protocol
- Has a high degree of credibility, both nationally and internationally.

The NCGAVS methodology provides raw biophysical coefficients. These coefficients require adjustment to fit the policy framework provided by the Offset System. The Technical Background Document provides considerable guidance on baseline assessment and potential reversals during the liability period. Therefore the majority of quantification work in this protocol involved generating and rationalizing adjustments to the raw NCGAVS coefficients. Net coefficients (after adjustments) are provided for implementing the practices of no-till and reduced till, and reversal coefficients for various types of reversals.

1.2 (b) QP workplan

In August 2005 the SMTWG established a terms of reference and workplan for soil management protocol development. A tillage system default coefficient protocol was identified as a priority due to considerable interest within the industry, and the high priority and specific guidance already provided in the Technical Background Document.

Agrologics Consulting (ie. Robert Janzen) was contracted in October 2005 to develop this protocol and prepare a technical seed document. The details of the quantification methodology were developed in collaboration with SMTWG. This began with a meeting of the entire SMTWG in Winnipeg on November 8 & 9, 2005, followed by numerous conference call and email exchanges between the consultant and the core group of the SMTWG. In December 2005 the consultant and core group met with various industry representatives, including potential project proponents or aggregators, to hear ideas and concerns relating to agricultural soil carbon projects and protocols. A draft protocol was prepared by Agrologics and presented to about 45 people at a science and stakeholder workshop on March 30 & 31, 2006 in Ottawa. Two break out groups of 12 people each provided recommendations to fine tune the protocol. These recommendations were incorporated into the protocol document, which was completed by April 24, 2006.

In May, 2006 the SMTWG chair met with quantification officials from the Offset System program authority to discuss next steps. It became evident that due to changes in the "Guide to Quantification Methodologies and Protocols" it would be necessary to revise the draft protocol document developed by the consultant. The SMTWG chair has provided these edits and additional wording to meet the template requirements. This was completed by November, 2006.

1.2 (c) QP development team leader and participants

This protocol was coordinated by the Soil Management Technical Working Group (see Table 1.2.1). Much of the work was conducted by Agrologics Consulting (Robert Janzen) in consultation with the lead and core group of the SMTWG. Table 1.2.2 provides more details on the credentials of the consultant, lead and core group members.

Table 1.2.1 Soil Management Technical Working Group Members

	Name	**Organization**	**Phone**	**Email**
Lead	Dennis Haak	AAFC	306-975-4772	haakd@agr.gc.ca
Core Group	Brian McConkey	AAFC	306-778-7281	mcconkeyb@agr.gc.ca
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Acronyms:	AAFC - Agriculture and Agri-Food Canada			
	NSAC - Nova Scotia Agriculture College			
	EC - Environment Canada			
	CCC - Climate Change Central			
	ECSWCC - Eastern Canada Soil and Water Conservation Centre			
	SCCC – Soil Conservation Council of Canada			
	SSCA – Saskatchewan Soil Conservation Association			

Table 1.2.2 Credentials of Key People

Robert Janzen, Agrologics Consulting	Ph.D. in Soil Science from University of Alberta. Areas of Expertise: agricultural protocols for offset credits (eg. pork protocol development), soil physical and biological processes impacting element and nutrient cycling, transformations, and GHG emission impacts.
Dennis Haak, Lead	B.Sc. (Agr) Soils Major. Senior Soil Resource Specialist. AAFC-PFRA. Over 20 years experience in developing, implementing, and evaluating beneficial soil management practices (BMPs) and programs for Canadian farming systems. Areas of Expertise: developing national BMPs, tillage systems, precision farming, soil erosion, GIS applications
Brian McConkey, Core Group	Ph.D. Soil and Water Conservationist. AAFC-Research Branch. Areas of Expertise: agricultural soil carbon sequestration research and modelling for NCGAVS, tillage systems, soil erosion, integrated soil/water/landscape studies
Robert Flick, Core Group	Senior Economist. AAFC-Agricultural and Environmental Policy Analysis. Past member of Working Group on Offsets. Areas of Expertise: agricultural related policy for offset system, biofuels, economic analysis / modelling of ag practices

1.2 (d) Technical review process

Table 1.2.3 provides a record of the key decisions made regarding this protocol from inception until this point.

Event	Attendees	Decision
Nov. 8 & 9, 2005 meeting, Winnipeg	Entire SMTWG & consultants	Direction for consultant on issue identification, analysis methodologies, and reporting requirements
Dec. 14, 2005 Meeting in Edmonton	SMTWG lead/core consultant, industry representatives	Outlined protocol approach, and received input & suggestions from industry representatives.
Dec. 15, 2005 meeting in Edmonton,	SMTWG lead/core SRG consultant	• Use NCGAVS coefficients for tillage system change • Analysis to validate and utilize the Census of

teleconferences on Jan. 20 & Feb. 8, many emails and one on one phone calls from Jan – Mar 06		Agriculture database on tillage adoption to develop baseline deduction factor • Analysis and development of reversal coefficients. • Development of specific activity definitions for tillage systems • Development of ecostratification basis for regionalization • Identification of monitoring and verification requirements • Identification of acceptable and prohibited activities within protocol
March 30 & 31, 2006 Science & Stakeholder Workshop	See Table 1.2.4	Reviewed, discussed, and ratified earlier decisions of core group and consultant, no major changes made
July - August, 2006	SMTWG Lead and Core Group	More detail and rationale developed for most recent document. Additional guidelines for monitoring / verification, and reversals*.

*Note: The changes made by the SMTWG Lead have not undergone significant technical review, aside from periodic communication with a few SMTWG members and the consultant to clarify any outstanding issues. Therefore, more technical review may be required, especially with regard to these aspects.

Table 1.2.4 Attendees at March 30-31, 2006 workshop in Ottawa

	Name	Affiliation	Email
1	Angers, Denis	AAFC	angersd@agr.gc.ca
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21	Janzen, Rob	Agrologics Consulting	robjan@shaw.ca
22	Jones, Ray	AgCert	rjones@agcert.com
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25	Legge, Eugene	Nfld	eugene.legge@nf.sympatico.ca
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34	Menard, Jean Francois	Horizon Vert	jfmenard@horizonvert.ca
35	Monreal, Marcia	AAFC	monreal@agr.gc.ca
36	Newcombe, Barry	IFAO	barry@fyfieldfarms.com
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39	Rochette, Philippe	AAFC	rochettep@agr.gc.ca
40	Saik, Rob	AgriTrends	rsaik@agritrend.com
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42	VandenBygaart Bert	AAFC	vandenbygaarta@agr.gc.ca
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1.3 Glossary of New Terms and Definitions

Definitions of technical terms are provided throughout the content of this document as they arise. They are more appropriately placed in the context of their use for this protocol, so they can be more easily understood and applied for their intended purpose.

Section II Quantification Development and Justification

Identifying Project SSRs

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

2.1 (a) Project SSRs: controlled, affected or related

The production of agricultural crops is a complex process involving significant flows of energy and materials. The project activity of changing tillage system to no-tillage or reduced tillage is integrated together with a large number of practices that are implemented at the farm and field scale. These practices include application of crop inputs (ie. seed, fertilizer, lime, pesticide, etc.), harvesting of crop outputs (ie. grain, silage, hay, etc.), and managing of remaining crop residues (eg. spreading, chopping, baling, grazing, etc.). Included in these processes is the transport of crop inputs from a farm storage facility to the field and crop outputs from the field to a farm storage facility. All of these practices and processes are directly controlled by the agriculture producer. The agriculture producer or a pool of agricultural producers represented by an aggregator are considered the project proponent for this protocol. Therefore, all SSR's associated with these practices and processes are considered as controlled in this protocol.

Upstream SSRs involve material and energy flows associated with the production and distribution of equipment and crop inputs that are purchased from an off farm source and are required for crop production. These SSRs are considered related because they are not directly controlled by the agriculture producer or project proponent in crop production.

Downstream SSRs are associated with the fate of end products of crop production, specifically the transportation and processing of grains, silage, and hay for utilization as livestock feed, biofuel production, or human food products. These are also considered related since they are not controlled by the agriculture producer or project proponent.

For this protocol no SSRs are considered affected because there are negligible changes in the demand for crop production inputs and crop production outputs. While a no-tillage or reduced tillage system may result in slightly higher herbicide demand, subtle changes in the type of farm equipment required, and possibly slight increases in crop yield, these small changes will have virtually no GHG impacts outside the scope of the project or protocol.

Figure 2.1.1 provides a flowchart of all SSRs, and draws a boundary around those that are controlled by the project proponent. Table 2.1.1 provides a description of these SSRs and indication if they are controlled, related, or affected.

Figure 2.1.1 Flowchart of GHG SSRs for Tillage Protocol (controlled within dotted box)

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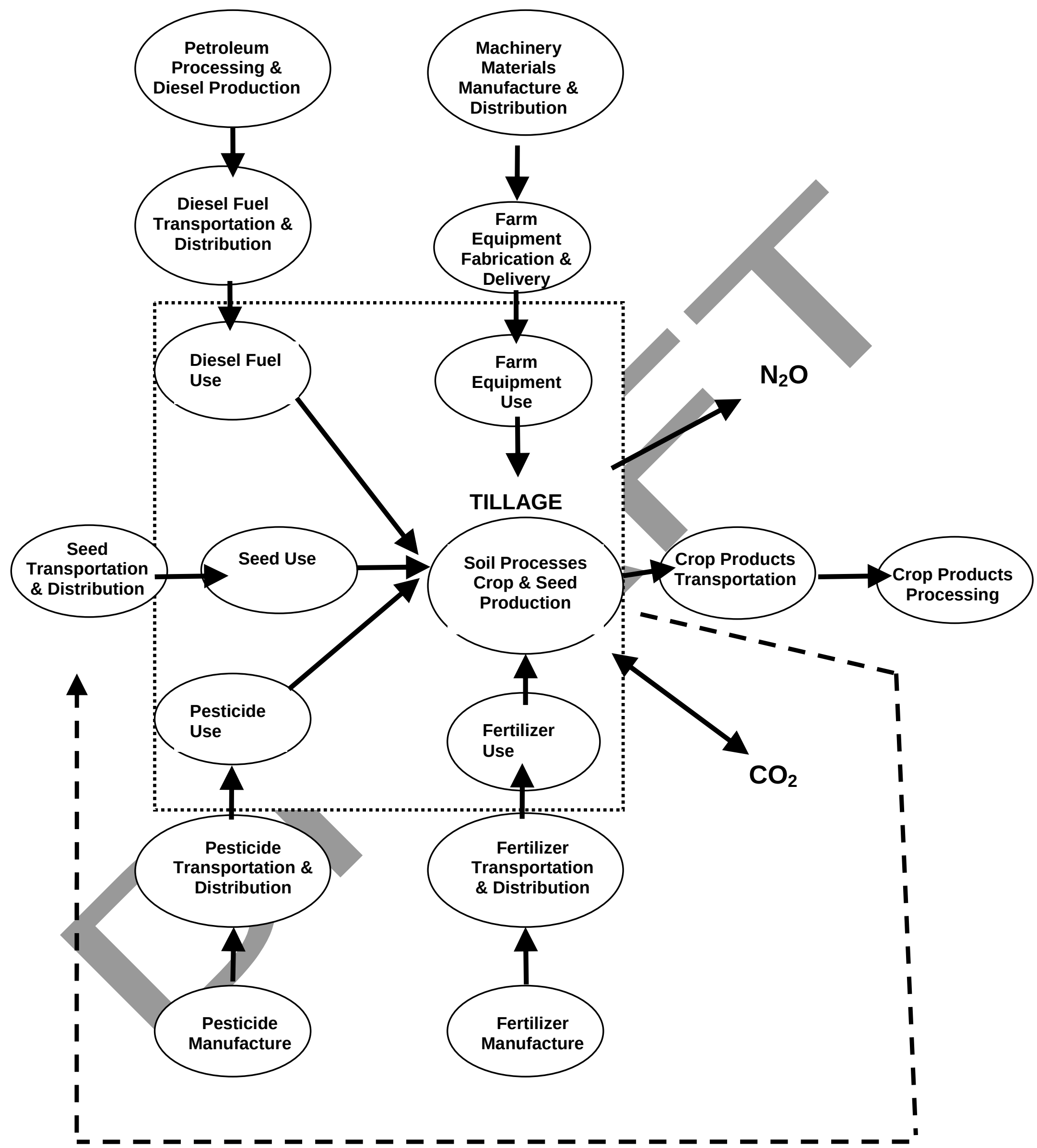

Petroleum Processing & Diesel Production
Machinery Materials Manufacture & Distribution
Diesel Fuel Transportation & Distribution
Farm Equipment Fabrication & Delivery
Diesel Fuel Use
Farm Equipment Use
N_2O
TILLAGE
Seed Transportation & Distribution
Seed Use
Soil Processes Crop & Seed Production
Crop Products Transportation
Crop Products Processing
Pesticide Use
Fertilizer Use
CO_2
Pesticide Transportation & Distribution
Fertilizer Transportation & Distribution
Pesticide Manufacture
Fertilizer Manufacture

Note: Seed production is an on site SSR if the proponent grows their own seed, but an upstream SSR if the proponent purchases seed from a seed supplier.

Table 2.1.1 Identification of controlled, affected, or related SSRs for the project

1. SSR	2. Description	3. Controlled, Related or Affected
Upstream SSRs		
Machinery Materials Manufacture & Distribution	Inputs of materials and energy needed to manufacture and distribute materials to suppliers of fertilizer applicator equipment.	Related
Farm Equipment Fabrication & Delivery	Inputs of materials and energy involved in the fabrication of fertilizer applicator equipment and the delivery to end user.	Related
Petroleum Processing & Diesel Production	Inputs of materials and energy involved in the discovery and processing of petroleum into diesel fuel. Because CH_4 can be emitted during processing of petroleum, fugitive emissions during production are included in this element.	Related
Diesel Fuel Transportation and Distribution	Inputs of materials and energy involved in the transportation and distribution of diesel fuel.	Related
Seed Production	Inputs of materials and energy involved in the growing, harvesting and processing of seed crops.	Related
Seed Transportation and Distribution	Inputs of materials and energy involved in the transportation and distribution of seed.	Related
Pesticide Manufacture	Inputs of materials and energy involved in the synthesis of pesticides including herbicides, insecticides, fungicides, rodenticides, etc.	Related
Pesticide Transportation & Distribution	Inputs of materials and energy involved in the transportation and distribution of pesticides	Related
Fertilizer Manufacture	Inputs of materials and energy involved in the production of nitrogen fertilizer.	Related
Fertilizer Transportation & Distribution	Inputs of materials and energy involved in the transportation and distribution of nitrogen fertilizer.	Related
Onsite SSRs		
Soil Processes, Crop Production	Flows of materials and energy that comprise the cycling of soil and plant	Controlled

	carbon and nitrogen, including deposition in plant tissue, decomposition of crop residues, stabilization in organic matter and emission as CO_2 and N_2O. The soils and crops are identified as one element, because NCGAVS integrated soil and cropping dynamics to derive net coefficients for C sequestration and N_2O emission.	
Equipment Use	Inputs of materials and energy involved in the operation of applicator equipment.	Controlled
Diesel Fuel Use	Inputs of materials and energy needed to power the farming equipment.	Controlled
Seed Use	Inputs of materials and energy embedded in the seed planted on the farm.	Controlled
Pesticide Use	Inputs of materials and energy embedded in the pesticides used to manage pests	Controlled
Fertilizer Use	Inputs of materials and energy embedded in the N fertilizer used to meet the crop requirement.	Controlled
Downstream SSRs		
Crop Products Transportation	Inputs of materials and energy involved in the transportation of crop products to commodity markets.	Related
Crop Products Processing	Inputs of materials and energy involved in the processing and distribution of end-products from crop commodities.	Related

Identifying Baseline Scenarios

2.2 Identification of the baseline

2.2 (a) Baseline scenario

The Offset System Technical Background Document (2005) provides some specific guidance on baseline. For example, section 195 states that *"the default approach will not require Project Proponents to provide historical information on practices implemented on the project*

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area. However, the removal factors must account for the fact that removals achieved by projects implemented before the Project Eligibility Start Date (01 January 2000) are ineligible to receive credits". Also, section 195 states *"the default approach will be designed to achieve accuracy at the aggregate level".*

The rationale for developing a protocol with these features was to provide a simplified solution to deal with the inherent complexities of estimating tillage system GHG impacts. These complexities include the following:

- The practices of no-tillage and reduced tillage have been adopted to varying extents by producers across Canada. The starting point of this adoption also varies greatly from within the past year to up to 20 years ago. Presently, there are still a significant number of producers that do not practice no-tillage or reduced tillage. There are also some producers that do not use these practices every year, and also a few that have reverted back to full tillage. However, the % of producers and land implementing these practices has continued to increase every year since the early 1990's (Census of Agriculture, AAFC-PFRA Seeding Surveys).
- The adoption rate based on % of producers may be somewhat more stable than adoption rate based on % of specific land parcels. In other words, because of changing land tenure (ownership or management control) some parcels of land are managed by different producers over time. (PFRA Seeding Survey, Haak, 2003)
- The amount of soil carbon sequestration and other GHG reductions due to a reduction in tillage intensity at one location can vary significantly from year to year, due to varying weather conditions, crop type, pest outbreaks, etc.
- The amount of soil carbon sequestration and other GHG reductions due to a reduction in tillage intensity in a given growing season can vary significantly from location to location, due to varying soil, landscape, and climate conditions.
- The rate of soil carbon sequestration due to a reduction in tillage intensity can change over time depending on how long reduced or no-tillage has been practiced, what the soil organic carbon content was at the time of the initial tillage change, and the soils capacity to store carbon. Related to this is the fact that all soils have a limit on how much soil carbon can be stored.

As a result of the guidance received it quickly became evident to the SMTWG **that the baseline must consist of a deduction of the raw coefficient value based on an estimate of GHG emission reductions and removals already achieved in the baseline.** Estimating baseline GHG emission reductions and removals is extremely challenging, due to the complexities listed above. Actually measuring soil carbon change and other GHG emission reductions is extremely costly, and is part of the rationale for developing a protocol based on default coefficients. Coefficients are based on annual removals and reductions, but it is difficult to know how long and how consistently specific parcels have been utilizing NT and RT practices.

The SMTWG decided that the only way to feasibly generate a baseline deduction was to base it on the adoption rate of the practice at a particular point in time. This point in time adoption rate (expressed as a percentage of land practicing NT and RT) is not necessarily the same as the percentage of total potential GHG emission removals (ie. soil carbon sequestration) already attained by these practices at this point. In fact, it is likely that the adoption rate percentage is higher than the % of total potential sequestration achieved, since most fields identified in the adoption rate survey as NT and RT will continue sequestering carbon for some time in the future. The SMTWG could have tried to adjust this adoption percentage lower to address this concern, but realized that the scientific methodology would be complex. Rather it was decided to address this issue in two other ways.

First, it was decided to use the crop year 1999 as the point in time to calculate the baseline adoption rates. This is consistent with the statement in the TBD which states “the removal factors must account for the fact that removals achieved by projects implemented before the Project Eligibility Start Date (01 January 2000) are ineligible to receive credits”. At the same time because projects using this protocol will likely not begin until 2007 or later, and the fact that NT and RT adoption rates continue to increase over time, a baseline based on adoption rate just prior to projects starting (ie. 2006) would be somewhat higher.

Secondly, while the baseline could be considered dynamic (based on the recent history of increasing adoption rates), the SMTWG recommends that the baseline be treated as static for a project’s first registration or crediting period. It is obvious that a static baseline will result in preventing an increase in the baseline deduction during this period, and therefore also helps to counteract the problem that the practice adoption rate underestimates the total % of potential soil carbon already sequestered. The justification for a static baseline is provided in the next section.

The application and integrity of the baseline deduction can be demonstrated with a simplified example. If there were only two tillage systems, no-tillage and conventional or full tillage, and the baseline adoption rate for NT was 30%, then the raw coefficient value would have to be reduced by 30%. Under this approach 100% of land in a given region would be eligible. If there was 100% participation in a project using this protocol the total offset credits gained would never exceed 70% of total actual tonnes reduced or removed by the practice on all lands in the region. It could reach 70% if the crediting period continued for as long as the coefficients used were valid estimates of actual soil carbon sequestered and if there were no further baseline deductions during this period.

Now consider another scenario for this same region whereby a different customized approach was made available. This customized approach used the same raw coefficients but did not apply any baseline deduction because only lands with a verifiable history of no NT were eligible. Assuming that a verifiable history of all eligible lands could be provided, this would amount to 70% of total seeded lands. That's because 30% of the lands were already practicing NT and not eligible. If all of these eligible lands participated in a project using this approach, the total offset credits gained would again reach 70% of total actual tonnes reduced or removed by the practice for all lands in the region.

2.2 (b) Static or Dynamic Baseline scenario

As mentioned in the previous section, increasing adoption rates of NT and RT in the recent past suggests that the baseline should be dynamic. However, as will be shown in section 2.5 the coefficients in this protocol are so low that any further baseline deduction is perceived to jeopardize the feasibility of most projects.

While the SMTWG respects the implications of a dynamic baseline, from a project planning and business perspective it is undesirable to implement an adjusted baseline deduction during a project's first registration or crediting period. In other words, project proponents need assurance of a fixed number of years stated up front by the program authority, in order to determine the feasibility of their project plan.

It is imperative that after a certain number of years the baseline must be reassessed if it is dynamic. The issue then becomes what is the suitable length of time for this initial registration or crediting period. While the SMTWG does not have a specific recommendation, a minimum of five years and possibly up to 10 years may be appropriate to ensure project feasibility.

It should be noted that this protocol can utilize coefficients based on different lengths of time. Generally, the coefficients based on shorter time periods are somewhat larger, for initial years. This is explained further in section 2.5. Therefore, if there was a scenario where the first registration period was only five years, it is likely that most project proponents would choose a five year coefficient if available, as opposed to a 10, 20, or 30 year coefficient. This is based on the likelihood that NT and RT adoption rates will continue to increase, which will result in an increased baseline deduction, and a further erosion of the net coefficient to the point that projects become unfeasible for the second registration period.

2.2 (c) Impact of Customized Approaches on Baseline Deductions

In section 194 of the TBD it states "*Removal factors will require adjustment on an on-going basis to ensure the accuracy of the factors are maintained. For example, an adjustment will be required if additional Project Proponents join the group using the default approach or if Project Proponents leave the group to use a customized approach. Adjustments to the removal factors will not affect the credits already issued".*

The TBD does not provide rationale for the above statements. However, the SMTWG recognizes conceptually that adjustments may be required for some projects using a customized approach for these same practices. More specifically if these projects provide a higher net emission removal or reduction where at least part of the reason for this higher credit is because the baseline deduction has been reduced or removed, then an adjustment is required.

This can be demonstrated, by building upon the same simplified example provided at the end of section 2.2 (a). In that example if the entire 70% of land eligible for a customized project participated, none of the remaining 30% would be eligible for the default protocol. Otherwise the total emission credits for the region would exceed the amount allowable under the initially applied baseline deduction. A more realistic scenario could be where the 30% with a previous NT or RT history initially enrol in the default protocol, and over time more and more of the remaining 70% enrol in a customized project with no baseline deduction. Under this scenario it would be prudent to develop a formula at the outset whereby a further deduction is consistently applied. This further deduction would ensure that as one approached a combined participation rate of 100%, the total amount of emission credits claimed would approach but never exceed the amount allowable based on the initial baseline deduction. This formula would apply to all possible scenarios, to ensure the same end result regardless of the proportion of land participating in each of the two protocol types.

Despite the conceptual validity of this adjustment, this would be extremely difficult to implement for the same reasons outlined in 2.2 (b). Therefore, the SMTWG recommends that an adjustment to account for participation rates in different protocol types be only done after the first registration or crediting period, as part of an overall baseline reassessment.

It should also be noted that not all customized approaches would require this type of adjustment. For example, there has been some interest in a protocol which utilizes the same baseline deductions as the default protocol, but uses a soil carbon measurement method to determine carbon changes in the project. This approach is attractive to top management producers who believe they can attain higher soil carbon gains than the typical average values provided by default coefficients. Under this scenario there would be potentially higher total emission credits for a region than what was allowed under an exclusive default approach. However, a reduction in coefficients would not be required since the baseline deduction is already applied, and this higher credit is justified by higher real carbon gains than what the default approach estimated.

2.2 (d) Accepted or rejected baseline scenarios

The SMTWG has received strong direction from the Offset System Technical Background Document (2005) for baseline development. The accepted baseline approach has been documented in the previous sections. It is somewhat difficult to classify this accepted baseline in terms of the possible baseline scenarios provided in the "Guide to Quantification Methodologies and Protocols". Nevertheless, it appears that the accepted baseline fits mostly closely with the "Performance Standard/Normalized Baseline Option".

The dominant rationale for rejecting other baseline scenarios is also related to the specific guidance provided by the TBD. In other words, for other customized approaches, some of the other baseline options may be more suitable. This is noted in Table 2.2.

Table 2.2.1 Possible Baseline Scenarios for Estimating GHG Emissions without Project

Baseline Option	
Historic benchmark	
• Description	Verifiable records of tillage systems on project fields before project startup
• Static or Dynamic	static
• Accept or Reject and Justify	Reject, default protocol species no requirement for historical records. May be suited for a customized approach
Performance standard / Normalized baseline	
• Description	A baseline representative of the industry, and aggregated to a regional level
• Static or Dynamic	Dynamic, NT and RT adoption rates continue to increase
• Accept or Reject and Justify	Accept, as directed by technical background document. However, baseline must remain static for initial registration or crediting period to maintain project feasibility
Comparison	
• Description	Benchmark sites managed as baseline activity concurrently with project activity
• Static or Dynamic	static
• Accept or Reject and Justify	Reject, default approach requires aggregation to large regions, too many benchmark sites required to achieve adequate representation. May be suited for a customized approach to represent small, local areas.
Projection-based	
• Description	Some future prediction of NT and RT adoption and their impact on GHG emission reduction/removal
• Static or Dynamic	dynamic
• Accept or Reject and Justify	Reject, historical aggregate data used in this protocol is much more accurate than future projections. Farming and cropping systems are too complex and vulnerable to global economic, social, technological, political, and environmental forces to be able to accurately predict.

Already registered	
• Description	n/a
• Static or Dynamic	
• Accept or Reject and Justify	

Source: *SMTWG*

Identifying Baseline SSRs

2.3 Identification of SSRs for the baseline

The SSRs for the baseline are identical to the project, because there is a high degree of functional equivalence between the baseline scenario and project activities. In other words both involve inputs of seed, fertilizer, pesticides, etc.; outputs of crop products; and the use of farm machinery to perform these activities.

The list of SSRs including decisions and rationale for controlled, affected, and related are the same for the baseline and the project. One can, therefore, use Table 2.1.1 as the list of baseline SSRs and the rationale provided in section 2.1 for these decisions.

Comparing Project and Baseline SSRs

2.4 Identify relevant SSRs to be included for quantification of the project and baseline

Most upstream SSRs can be excluded or deemed as not relevant for both the baseline and project, because all activities are not controlled by the proponent and there is negligible change in the quantity of SSR's between project and baseline. There are two exceptions that are included for quantification as they have consistent albeit small impacts. These include energy consumption in the production of herbicides and energy consumption in the fabrication of farm equipment (including raw materials such as steel). These SSRs are included because a change in tillage systems from FT to RT or NT results in a greater use of herbicides rather than tillage to control weeds. Weed control is one of the primary reasons for tillage, so eliminating tillage requires a need for other weed control options, of which herbicides is a primary method. These key SSRs are more fully described and quantified in section 2.5.

On site SSRs include the application of crop inputs (seed, fertilizer, pesticides, etc.), the production and removal of crop outputs (grain, silage, hay, straw, etc.), and the changes that occur in the soil and surrounding environment as a result of the cropping cycle. The primary impacts of a change in tillage system from full tillage to reduced tillage or no-tillage are:

- An increase in soil carbon content or carbon sequestration (ie. GHG removal)
- A decrease in N_2O emissions, and
- A decrease in fuel use in the crop production system

The mechanism of C sequestration associated with NT compared to FT is consistently described in the scientific literature as enhanced micro-aggregate formation and stabilization of C due to decreased macro-aggregate turnover (cf. Six *et al.* 1999, Calderón *et al.* 2000, Denef *et al.* 2004). Changing from FT to NT has a smaller impact on N_2O emissions but consistent reductions have been found in the Canadian prairie region (Rochette, Worth, et. al. 2005). A decrease in fuel use is associated with the change from tillage use to herbicide use, and the fact that tillage operations have significantly higher power requirements and thereby higher energy consumption and GHG emissions. Energy consumption coefficients for fuel use, and the upstream SSRs identified previously for quantification, have been developed by Smith and Nagy. All of these key SSRs are explained more fully in section 2.5.

There are other on site SSRs that may have GHG impacts resulting from a tillage change, but they are negligible. These impacts are described and rationalized as follows.

- There is an argument that NT and RT may result in lower fertilizer use, due to improved soil productivity and nutrient use efficiency. However, fertilizer application rates are also impacted by many other factors, such as yield goals, growing conditions, crop and crop input prices, etc. While fertilizer reduction may result in lower N_2O emissions it is desirable to address this practice through other protocols. Furthermore the coefficients used in this protocol to quantify the key SSRs involving the change in tillage assume an average rate of fertilizer application based on recommended rates.
- Considerable research has looked at various seeding rates under different conditions. While no till systems often use wider row spacing and narrower openers, the recommended seeding rate does not change significantly (Zylstra, AAFRD)
- The use of pesticides and farm equipment does change for different tillage systems as already discussed. These impacts are included within the key SSRs already identified, namely energy consumption associated with farm equipment use, farm equipment fabrication, and herbicide production.
- The impacts of tillage system on CO_2 and N_2O in the soil environment are dealt with in the key SSRs. The other potential GHG impact is methane. Methane is produced in soil only under anaerobic conditions (Topp, 1997). Tillage has little or no impact on CH_4 emissions, since these operations are conducted under aerobic conditions and have little impact on whether a soil becomes anaerobic.

Finally, downstream SSRs include the transportation and processing of crops. A change from FT to RT or NT may result in subtle crop output changes such as the following:

- more diversified crop rotations resulting in a greater diversity of crop types
- increased crop yield due to improved soil productivity and soil moisture conservation

Any significant GHG impacts relating to crop transportation and processing would have to be due to a change in the overall crop quantity impacting transportation cost, or a shift in crop type that impacts processing intensity. These types of impacts have not been accessed in sufficient detail by the research community to determine their impact. It is recognized that there are many other factors that impact downstream GHG impacts such as market demands for crops, and weather related impacts on crop quantity and quality. There are also many counteracting trends that would suggest this impact is very small. For example, while crop yields have improved with NT, the overall crop volume may not be impacted because of the shift to pulse and oilseed crops which are generally lower yielding than cereal crops.

2.4 (a) Baseline and Project SSR comparison

Table 2.4.2 Compare controlled, affected or related baseline and project SSRs

1. 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 Operation				
Machinery Materials Manufacture & Distribution	Related	Related	Include	Emission change
Farm Equipment Fabrication & Delivery	Related	Related	Include	
Petroleum Processing & Diesel Production	Related	Related	Exclude	Not controlled by proponent, negligible change from baseline to project
Diesel Fuel Transportation & Distribution	Related	Related	Exclude	
Seed Production	Related	Related	Exclude	
Seed Transportation & Distribution	Related	Related	Exclude	
Pesticide Manufacture	Related	Related	Include	Emission change
Pesticide Transportation & Distribution	Related	Related	Exclude	Not controlled by proponent, negligible change from baseline to project
Fertilizer Manufacture	Related	Related	Exclude	
Fertilizer Transportation & Distribution	Related	Related	Exclude	
On-site SSRs during Operation				
Soil Processes, Crop Production	Control	Control	Include	Emission change
Equipment Use [1]	Control	Control	Exclude	Negligible change from baseline to project
Diesel Fuel Use	Control	Control	Include	Emission change
Seed Use	Control	Control	Exclude	Negligible change from baseline to project
Pesticide Use [1]	Control	Control	Exclude	
Fertilizer Use	Control	Control	Exclude	
Downstream SSRs during Operation				
Crop Products Transportation	Related	Related	Exclude	Not controlled by proponent, negligible change from baseline to project
Crop Products Processing	Related	Related	Exclude	

Note: Refer to detailed explanation in section 2.4 prior to this table for further justification for exclusion

[1] A change in tillage system does impact equipment and pesticide use, but these impacts are already quantified in the Diesel Fuel Use (on site), machinery materials and equipment fabrication (upstream), and pesticide manufacture (upstream) SSRs.

Quantifying Project and Baseline SSRs

2.5 Quantification of reductions/removals/reversals of relevant SSRs

This section describes the scientific methodology for quantifying relevant SSRs and provides specific emission removal and reduction factors to be used by projects under this protocol. The outline of this section does not follow the outline provided in the "Guide to Quantification Methodologies and Protocols" template document, but rather follows a natural progression suited for the technical nature of this protocol. However, it covers all aspects and fulfills all requirements of the template.

As stated in the Introduction section, the Offset System Technical Background Document (2005) states that this *"quantification protocol will use removal factors to quantify carbon stock changes. Project Proponents that choose to use the protocol will multiply the verified number of hectares over which the practice has been implemented by the removal factor in the protocol. If there is a change in practice that could result in the release of carbon removed, the Proponent will calculate the reversal using a reversal factor set out in the protocol"* These statements imply that the protocol will estimate and not measure GHG emission changes.

These estimates will utilize widely accepted coefficients that are based on a consistent set of activity definitions. Therefore, projects will essentially need to ensure that eligible activities are undertaken, and use the coefficients that are applicable for specific activities in specific regions to calculate the emission reduction or removal.

The emission reduction and removal coefficients used in this protocol are based on extensive research on tillage systems across Canada. Canada is considered a world leader in the development and adoption of no-till and reduced till systems, and this includes a rich history of scientific field based research. Originally this research focused primarily on soil carbon impacts to improve soil productivity. As climate change and GHG issues came to the forefront, the tillage practices were investigated in more detail to determine other GHG impacts including N_2O and energy consumption. Much of this research was driven by the need to provide accurate national estimates of GHG emissions for the United Nations Framework Convention on Climate Change (UNFCCC).

Canada's research in tillage systems has contributed significantly to the development of acceptable accounting methodologies overseen by the International Panel on Climate Change (IPCC). The IPCC has typically identified three general tiers of emission factors, with each tier progressively providing greater accuracy. While the IPCC often provides Tier 1 emission factors, it provides the option for countries to develop Tier 2 and 3 approaches that are specifically designed to address unique quantification issues in that country. Canada has again been in the forefront of developing higher tier methodologies in relation to tillage systems. This work is coordinated by the National Greenhouse Gas Accounting and Verification System (NCGAVS). For the most part the quantification methodology used in this protocol is based on the latest coefficients developed by the NCGAVS. The NCGAVS methodology is deemed most appropriate for this protocol for the following reasons:

- provides emission factors for all agricultural regions of Canada
- considers research from all credible science sources
- emission factors are updated on a regular basis
- has the greatest level of national and international credibility.

2.5 (a) Regional Ecostratification

Before describing the detailed quantification methodology of each SSR it is necessary to describe the concept of regional ecostratification and provide rationale for the regional areas prescribed in this protocol. The Offset System technical background document (2005) states that … *the default approach will be designed to achieve accuracy at the aggregate level.* Therefore, idea of generating emission factors for relatively large regions is prescribed by the TBD.

In Canada most analysis of farm management and soil/landscape data is done using a well defined system of ecostratification. This system was been developed by various federal departments in the 1970's and has become widely accepted by the scientific community (see http://sis2.agr.gc.ca/cansis/intro.html). It utilizes a hierarchal classification starting with ecozones, which further delineate to ecoregions, ecodistricts, and soil landscapes. The NCGAVS methodology utilizes this system.

To determine the appropriate regional areas for use in this protocol it was important to ensure that:

- the annual cropland within one region was characterized by somewhat similar GHG emission reduction or removal coefficients, specific activity definitions, and historical adoption trends for no-till and reduced tillage
- there was a significant difference between regions in at least one of the three criteria mentioned in the previous bullet.
- the same regional areas could be used for all three criteria mentioned in the first bullet.

The regional areas used in this protocol are the same as what is used in the NCGAVS methodology for quantifying soil organic carbon change. These areas are essentially groups of ecozones and ecoregions, as shown in Table 2.5.1. The ecozones and ecoregions in this table are unique and must be added together. The ecodistrict numbers are smaller polygons which represent the same total area as the ecozones and ecoregions. Figure 2.5.1 shows the location of these regions within Canada.

Table 2.5.1 Designation of Protocol Areas within Canada's Ecostratification Framework

Protocol Area	Ecozone / *Ecoregion*	Ecodistricts
1 East	7 - Atlantic Maritime 6 - Boreal Shield (Newfoundland)	452 - 539
2 East Central	6 - Boreal Shield (eastern Ontario, Québec) *132 - St. Lawrence Lowlands* *133 - Frontenac Axis* *134 - Manitoulin-Lake Simcoe* *135 - Lake Erie Lowland*	400 - 452, 540 - 572
3 Parkland	6 – Boreal Shield (AB, SK, MB, NW Ont.) 9 – Boreal Plains 14 - Montane Cordillera (Alberta) *156 – Aspen Parkland* *158 – Fescue Grassland* *162 - Lake Manitoba Plain* *163 - Southwest Manitoba Uplands*	353 - 391, 574 - 766, 839 - 855, 1016 - 1019
4 Dry Prairie	157 – Moist Mixed Grassland 159 – Mixed Grassland 160 – Cyprus Upland	767 - 838
5 West	13 - Pacific Maritime 14 - Montane Cordillera (BC)	938 - 1015

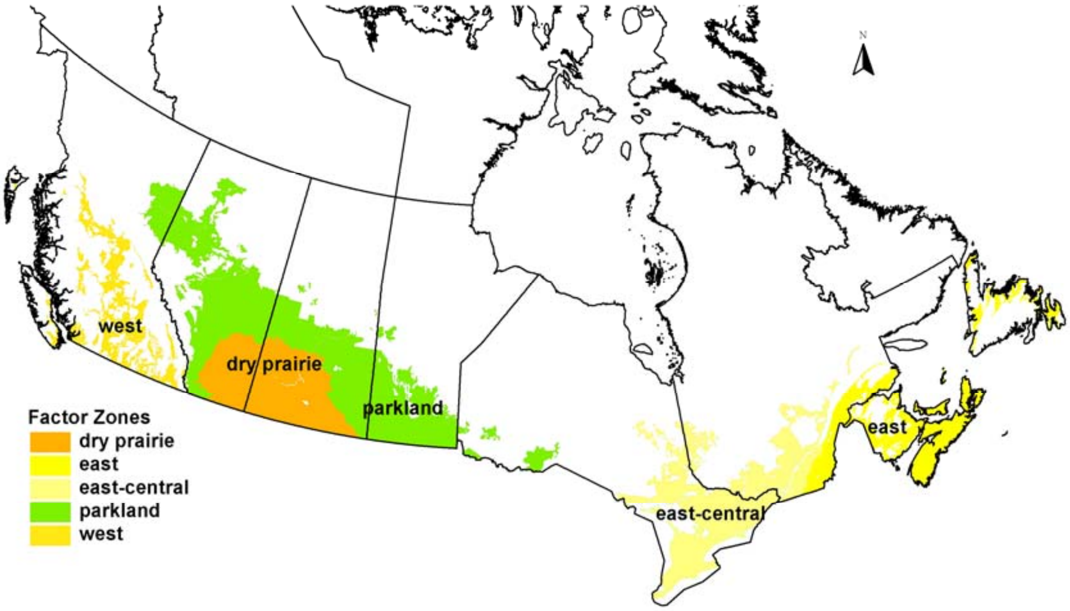

Figure 2.5.1. The boundary between Dry Praire and Parkland is the Black-Dark Brown soil zone boundary. The east-central and east is the boundary is that between the Atlantic Maritime and Mixed Wood Plains ecozones. From McConkey 2006.

2.5 (b) Soil Organic Carbon Change or Sequestration

The following summary briefly highlights the scientific foundation for considerations in this protocol, concerning soil organic carbon (SOC) coefficients, reversals, and impacts on credit registration periods.

The mechanism of carbon sequestration associated with NT compared to FT is consistently described in the scientific literature as enhanced micro-aggregate formation and stabilization of carbon due to decreased macro-aggregate turnover (cf. Six *et al.* 1999, Calderón *et al.* 2000, Denef *et al.* 2004).

This mechanism has implications for the stability of sequestered SOC. According to Liebig *et al.* (2005), "rates of soil and whole-ecosystem CO_2 flux from cropland indicated short-term C loss/gain from specific management practices mirrored long-term changes in SOC". In other words, "changes in SOC occur predominantly in `young' or labile fractions" (Janzen *et al.* 1998). Rhoton (2000) provides evidence that statistically significant increases in SOC are detected by physical measurement after four years of FT. West and Post (2002) used evidence from long-term agricultural experiments to conclude that "carbon sequestration rates, with a change from CT to NT, can be expected to peak in 5 to 10 yr with SOC reaching a new equilibrium in 15 to 20 yr". Other investigators conclude that the carbon sequestered using NT are quickly reversed if FT is resumed (Dick *et al.* 1998, Stockfisch *et al.* 1999).

The NCGAVS project (McConkey, 2006) used Century 4.0 model of SOC dynamics with Canadian data to derive a mathematical representation of the change in SOC associated with the shift in practice to or from NT. The basic equation, which is consistent with the findings described in the previous paragraph, is as follows:

$$^\wedge C(t) = {^\wedge C_{max}} * [1 - \exp(-k * t)]$$

where : $^\wedge C(t)$ is the change in SOC with time (t), since the management change
$^\wedge C_{max}$ is the maximum total SOC change, and
k is the rate constant

Figure 2.5.2 shows an example of this relationship. Many users prefer linear coefficients of SOC change. These can be calculated as follows:

$$f = {^\wedge C_{max}} * [\exp(-k * t_1) - \exp(-k * t_2)] / (t_2 - t_1)$$

where f is the effective linear coefficient (Mg ha^{-1} yr^{-1}) of SOC change between times t_1 and t_2 from the practice change.

Effective linear coefficients for three time periods and various tillage system changes are shown in Table 2.5.2.

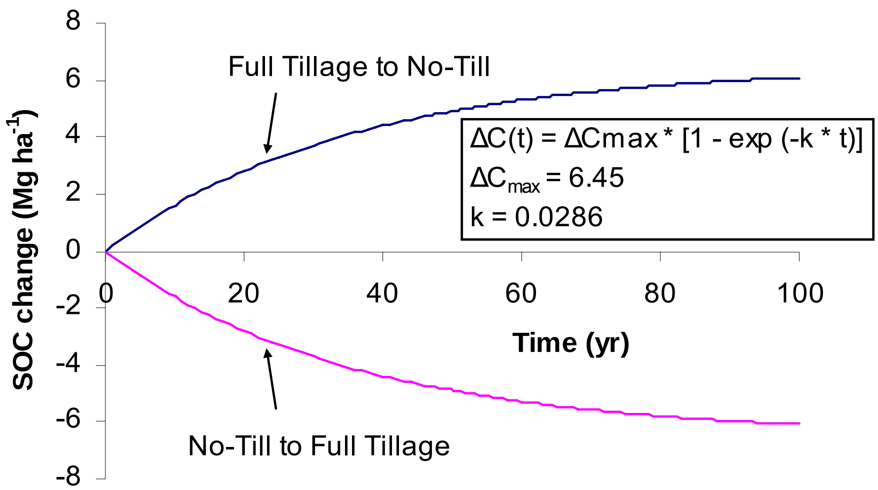

Figure 2.5.2 SOC change from change in management (effect of changing from full tillage to no-till in the parkland zone is shown). From McConkey 2006.

Table 2.5.2 Effective raw linear coefficients used in the NCGAVS project to predict soil organic carbon change from tillage practice change. From McConkey 2006.

	Tillage System Change	Effective Raw Linear Coefficient for Specified Years After Practice Change[1]					
		5 yr (Mg C ha^{-1} yr^{-1})	5 yr (Mg CO_2 ha^{-1} yr^{-1})	10 yr (Mg C ha^{-1} yr^{-1})	10 yr (Mg CO_2 ha^{-1} yr^{-1})	20 yr (Mg C ha^{-1} yr^{-1})	20 yr (Mg CO_2 ha^{-1} yr^{-1})
East	FT-to-NT	0.07	0.27	0.07	0.25	0.06	0.23
	FT-to-RT	0.06	0.21	0.05	0.20	0.05	0.18
	RT-to-NT	0.02	0.09	0.02	0.08	0.02	0.08
East-Central	FT-to-NT	0.12	0.43	0.11	0.41	0.10	0.36
	FT-to-RT	0.05	0.17	0.04	0.16	0.04	0.14
	RT-to-NT	0.08	0.28	0.07	0.26	0.06	0.23
Parkland	FT-to-NT	0.17	0.63	0.16	0.59	0.14	0.52
	FT-to-RT	0.06	0.23	0.06	0.22	0.05	0.20
	RT-to-NT	0.09	0.33	0.08	0.31	0.07	0.27
Dry Prairie	FT-to-NT	0.12	0.44	0.11	0.41	0.10	0.37
	FT-to-RT	0.04	0.15	0.04	0.15	0.04	0.13
	RT-to-NT	0.05	0.20	0.05	0.19	0.05	0.17

Important Caveat: This is a historical document; the scope of the proposed federal GHG offset system has not been finalized. This protocol was not approved by the federal government and may not reflect current federal policy decision.

West	FT-to-NT	0.06	0.21	0.05	0.20	0.05	0.19
	FT-to-RT	0.01	0.03	0.01	0.03	0.01	0.03
	RT-to-NT	0.05	0.17	0.04	0.16	0.04	0.15

As already discussed in section 2.2 (b) the length of coefficient chosen by project proponents will likely be the length of the first registration period, because a reassessment of the baseline after the first registration period will likely deem further projects unfeasible. The length of the first registration period has not been clearly defined. An eight year period has been suggested by Offset System program officials and obviously project proponents would desire this period to be as long as possible for the reason stated at the beginning of this paragraph. Therefore, for the remainder of this protocol 10 year coefficients for SOC are used.

From Figure 2.5.2 it is clear that the impact of a management change from NT to FT is exactly opposite the FT to NT relationship. McConkey et al discuss the issue of reversals extensively and conclude that SOC effect of practice change in one direction is exactly negative of the SOC effect of practice change in the opposite direction. Therefore, the negative values of the raw linear coefficients provided in Table 2.5.2 could be considered appropriate for practice changes in the opposite direction.

The coefficients provided in Table 2.5.2 are considered raw coefficients in that they need to be adjusted to account for baseline. This is resolved in section 2.5 (f) and (g).

2.5 (c) N_2O Reduction Quantification

The impact of cropping systems and specifically tillage system on N_2O emissions is much less understood than SOC impacts. Rochette, Worth and others have developed a methodology in 2005 for use in the NCGAVS which considers all relevant and up to date scientific information. The NCGAVS methodology uses the following basic equation.

Annual N_2O (kg N_2O-N) = N inputs (kg N) * Emission Factors (kg N_2O-N kg^{-1} N) * Ratio Factors (unitless)

where N inputs are annual inputs in the form of commercial fertilizer,
Emission factors include climate, topography, irrigation, fallow frequency, drainage, and indirect emissions associated with volatilization and redeposition of NH_3 and NO_x,
and Ratio factors include tillage system and spring thaw

As pointed out by Rochette et al tillage impacts on N_2O potentially occur due to changes in nitrogen cycling due to changes in SOC, as well as impacts on soil moisture, temperature, and density. A review of scientific studies across Canada show no significant impacts of tillage system on N_2O emissions, except in the prairie region, where modest but significant reductions due to no till were found.

To quantify the impact of tillage system on N_2O emissions one only needs to consider the factors that are part of this calculation subset. One can assume that tillage system does not

have any significant impact on the other factors, such as climate, topography, fallow, drainage, spring thaw, etc. Some of these factors would not change since they are independent of management. Other factors such as fallow frequency may change as a result of a tillage system change, but these would be addressed in a separate fallow protocol, so they can be ignored here.
The specific equation to quantify N_2O emission reduction impacts of tillage system is as follows:

$$N_2O\text{-}N_{SOIL} = N_{FERT} * EF_{CTI} * RF_{TILL}$$

where $N_2O\text{-}N_{SOIL}$ are direct N_2O emissions from the soil resulting from nitrogen application to crops, expressed as kg N_2O-N /ha/year. Note that direct soil emissions are not crop specific and are considered similar for all crop types

N_{FERT} is the nitrogen application rate in kg of actual N/ha/year. For the purpose of this protocol, a single typical rate of N fertilizer is used, 75 and 50 kg / ha for the dry prairie and parkland regions, respectively. As discussed previously, tillage systems could have some impact on fertilizer inputs, but these would need to be addressed in a separate protocol which considers many other factors contributing to fertilizer rates.

EF_{CTI} is the emission factor related to climate, topography and irrigation. It is based on studies which measured N_2O flux from varying rates of N fertilizer addition. EF_{CTI} factors are generated for each Soil Landscape of Canada (SLC) class to account for differences in climate and proportion of land in various slope positions. This protocol calculates a weighted average value for each of the two prairie regions based on the percentage of land occupied by each SLC in each of these regions. The results in the prairies are somewhat variable but are conservative compared to the IPCC Tier I value of 0.0125. The values are 0.00611 and 0.00278 kg N_2O-N / kg N for the parkland and dry prairie regions, respectively.

and, RF_{TILL} is the unitless ratio factor associated with the impact of tillage systems on N_2O emissions. In the prairie region of Canada lower N_20 emission rates are associated with no till and minimum. An RF_{TILL} = 0.8 is used for both no-till and reduced till, and 1.0 for full till.

Using the above equation emission reduction factors for tillage systems can be calculated as shown in Table 2.5.3. Note that this table also shows various unit conversions with the end result expressed as Mg $C0_{2\ equiv}$ / ha.

Table 2.5.3 Raw N_2O emission reduction coefficients for tillage systems in the Prairie region

Parameter	Units	Region

		Dry Prairie	Parkland
N_{fert}	Kg / ha / yr	50	75
EF_{CTI}	Kg N_2O-N / kg N	0.0028	0.0061
FT RF_{Till}		1.0	1.0
NT and RT RF_{Till}		0.8	0.8
FT N_2O factor	Kg N_20-N / ha	0.139	0.458
	Kg N_20 / ha *	0.219	0.720
	Mg $CO_{2\ equiv}$ / ha **	0.068	0.223
RT and NT N_2O factor	Kg N_20-N / ha	0.111	0.367
	Kg N_20 / ha	0.175	0.576
	Mg $CO_{2\ equiv}$ / ha	0.054	0.178
FT to NT	Mg $CO_{2\ equiv}$ / ha / yr	0.014	0.045
FT to RT		0.014	0.045
RT to NT		0.000	0.000
NT to FT		-0.014	-0.045
RT to FT		-0.014	-0.045
NT to RT		0.000	0.000

Note: * Kg N_20 / ha = Kg N_20-N / ha * 44 / 28
** Mg $CO_{2\ equiv}$ / ha = Kg N_20 / ha * 310 / 1000

2.5 (d) Energy Consumption Quantification

As mentioned in section 2.4 moving to no-till and reduced till systems results in lower energy consumption. This is described more fully as follows.

A key consideration in the quantification of GHG emission removals and reductions associated with NT and RT is the decreased consumption of energy. Dumanski *et al.* (1998) cite scientific literature reporting that energy use in NT is 44 to 55 % of that used in FT. The estimates of relative energy consumption used in the GHGFarm documentation (Helgason 2005) are somewhat more conservative. The energy consumption determinations from the GHGFarm represent the consensus of expert interpretation of Canadian data, so they are used in this protocol.

- Upstream Energy Consumed During Herbicide Production

With a change from FT to RT or NT there is an increased reliance on herbicides rather than tillage to control weeds. Changes in the types of herbicide used may also vary, however, the most significant change is typically increased use of glyphosate under RT and NT. (PAMI, Direct Seeding Manual, 1991). Energy consumption coefficients for NT, RT, and NT have been generated by Smith and Nagy, reported by Helgason et al in the GHGFarm Model 2005, and are further shown in Table 2.5.4. These coefficients reflect the energy consumed or

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GHG emitted during the production of herbicides, and show increased values for NT and RT compared to FT, due to the increased use of herbicides.

- Upstream Energy Consumed During the Fabrication of Farm Machinery

With a change from FT to RT or NT there is change in the use of certain types of farm equipment. For example, herbicide sprayers are used more frequently, and tillage equipment is used less frequently. Tillage equipment is substantially heavier than spraying equipment and has greater power requirements to operate. There is greater energy consumption in the fabrication of tillage equipment and larger tractors required to operate this equipment. Therefore, energy consumption values associated with fabrication of farm machinery decreases when changing from FT to RT and ZT. These coefficients have also been developed by Smith, Helgason et. al. and are also shown in Table 2.5 4.

- Onsite Energy Consumed During Crop Production

The third component of energy consumption is the fuel consumed during operation and maintenance of farm equipment. For the same reasons as described in the previous bullet NT systems will consume less fuel to operate sprayers compared to tillage equipment. These coefficients have also been developed by Smith, Helgason et. al. and are also shown in Table 2.5 4.

Table 2.5.4 Crop Type raw energy consumption for Tillage Systems.

Eco-Area	Tillage system	Crop Rotation (Annuals)	Fuel	Herbicide	Machine	Total *
				(GJ ha^{-1} yr^{-1})		Mg CO_{2e} ha^{-1} yr^{-1}
Parkland & West	FT	All	2.63	0.16	0.82	0.2773
		Fallow	2.35	0.06	0.66	0.2391
	RT	All	2.39	0.23	0.77	0.2574
		Fallow	1.71	0.11	0.51	0.1789
	NT	All	1.43	0.46	0.48	0.1692
		Fallow	0.93	0.60	0.28	0.1207
Dry Prairies	FT	All	2.02	0.16	0.67	0.2174
		Fallow	1.62	0.00	0.37	0.1571
	RT	All	1.78	0.23	0.62	0.1975
		Fallow	1.16	0.07	0.25	0.1145
	NT	All	1.42	0.46	0.48	0.1684
		Fallow	0.34	0.78	0.04	0.0639

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East & East-Central	FT	Corn	3.29	0.08	2.75	0.4624
		Soybean	3.11	0.08	2.75	0.4479
		Grains	2.83	0.16	2.75	0.4286
	RT	Corn	2.30	0.12	2.18	0.3441
		Soybean	2.13	0.12	2.18	0.3303
		Grains	1.80	0.24	2.18	0.3087
	NT	Corn	1.90	0.12	2.01	0.2998
		Soybean	1.72	0.12	2.01	0.2852
		Grains	1.34	0.24	2.01	0.2596

Note: Conversion factors are as follows: fuel – 0.081, herbicide – 0.043, and machinery – 0.070 Mg $CO_{2\ equivalent}$ GJ^{-1}. Source: Helgason et al, 2005

The coefficients in Table 2.5.4 are further simplified to provide single values for each tillage system within each region, as shown in Table 2.5.5. In other words the impact of crop type or fallow is eliminated, since the purpose of this protocol is to quantify tillage differences only. Differences based on crop type or fallow frequency could be addressed in protocols specific to these practices. Nevertheless, to maintain integrity the simplified coefficients reflect the proportion of land in these various crop types in each region as reported by the 2001 Census of Agriculture.

Table 2.5.5 Weighted raw energy consumption for Tillage Systems.

Eco-Area	**Tillage system**	**Crop Rotation (Annuals)**	**Proportion of Land ***	**Weighted Total**
			%	**Mg CO_{2e} ha^{-1} yr^{-1}**
Parkland & West	FT	All	0.902	0.2736
		Fallow	0.098	
	RT	All	0.902	0.2497
		Fallow	0.098	
	NT	All	0.902	0.1645
		Fallow	0.098	
Dry Prairies	FT	All	0.777	0.2040
		Fallow	0.223	
	RT	All	0.777	0.1790
		Fallow	0.223	
	NT	All	0.777	0.1451
		Fallow	0.223	
East	FT	Corn	0.376	0.4466

& East-Central		Soybean	0.276	
		Grains	0.348	
	RT	Corn	0.376	0.3280
		Soybean	0.276	
		Grains	0.348	
	NT	Corn	0.376	0.2817
		Soybean	0.276	
		Grains	0.348	

Note: Weighted total = sum (proportion * totals $_{\text{specific crop types from Table 2.5.4}}$)

Raw energy related coefficients for tillage practice change are generated from Table 2.5.5, and shown below in Table 2.5.6.

Table 2.5.6 Raw energy consumption coefficients for Tillage System change

Tillage System Change	Region (Mg CO_{2e} ha^{-1} yr^{-1})		
	Parkland, West	Dry Prairie	East & East Central
FT to NT	0.1091	0.0589	0.1649
FT to RT	0.0239	0.0250	0.1186
RT to NT	0.0852	0.0339	0.0463
NT to FT	-0.1091	-0.0589	-0.1649
RT to FT	-0.0239	-0.0250	-0.1186
NT to RT	-0.0852	-0.0339	-0.0463

2.5(e) Activity Definitions Used in Generating Coefficients

The Century 4.0 model used to generate SOC coefficients requires the input of specific tillage definition parameters. These are shown in Table 2.5.7.

Table 2.5.7 Definitions of tillage systems used for NCGAVS SOC change

Zone	Tillage System	Description[1]
East	Full Till	Always at least spring cultivation, usually fall and spring cultivation, often fall plowing.
	Reduced Till	Always spring tillage, some fall tillage, no plowing
	No Till	Up to two passes with low-disturbance openers
East-Central	Full Till	Always at least spring cultivation, usually fall and spring cultivation, often fall plowing
	Reduced Till	Always spring tillage, some fall tillage, no plowing

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	No-Till	Up to two passes with low-disturbance openers
Parkland	Full Till	Spring and fall tillage, 5 to 6 cultivations on summerfallow,
	Reduced Till	One (occasionally two) cultivations in spring, 2 cultivations on summerfallow
	No-Till	Up to two passes with low disturbance openers, rare spring cultivation, no cultivations on summerfallow
Dry Prairie	Full Till	Spring and fall tillage, 5 to 6 cultivations on summerfallow,
	Reduced Till	One cultivation in spring, 2 cultivations on summerfallow
	No-Till	Up to two passes with low disturbance openers, no cultivations on summerfallow,
West	Full Till	Fall and spring cultivation, rare spring tillage, 4-6 cultivations on summerfallow
	Reduced Till	Always spring tillage, some fall tillage, up to 2 cultivations of summerfallow
	No-Till	Up to two passes with low disturbance openers, no cultivations on summerfallow,

[1] Definitions are based on primary tillage, up to two shallower operations allowed within one week of primary tillage operation. For example, harrowing a few days after primary tillage would not affect the definition of tillage system

Source: McConkey, 2006

Activity definitions for N_2O and energy consumption coefficients are not readily available. However, discussions with science experts concluded that the definitions used for these other coefficients is very close to the definitions shown in Table 2.5.7.

As mentioned at the outset in section 1.1a, it is imperative that activity definitions are consistent throughout the protocol. In other words the same definitions must be used for all aspects of quantification, baseline assessment, monitoring, and verification. Nevertheless, as will be discussed in section 3 it became necessary to adjust the wording of the definitions shown in Table 2.5.7 to enable proper monitoring and verification processes. However, these adjustments did not change the integrity or meaning.

2.5 (f) Generating Appropriate Tillage System Adoption Rates for Baseline Assessment

The rationale for a static, regionally aggregated baseline deduction based on adoption rate of no till and reduced till for the year 1999 has already been described in section 2.2. This section describes the methodology used to generate, validate, and utilize the most appropriate adoption rate data for this purpose.

There are a number of data sets that provide information on adoption rate of no-till and reduced till. However, the only data source with national coverage is the Census of Agriculture.

A major issue with all data sets is the method by which data is collected, and more specifically the definition of no-till and reduced till used for these purposes. A review of these data sets has concluded that definitions vary and often are unclear or open to varying interpretation. This issue must be resolved to ensure that the data used for baseline analysis is based on a tillage definition that is consistent with the activity definitions used to generate the coefficients. A summary of existing data sets that were considered are shown in Table 2.5.8.

A comparison of data sets revealed that the Census of Agriculture data agreed reasonably well with a simple tillage system question used in an AAFC prairie weed survey in the mid 1990's. These data sets overestimated NT and RT, when comparing with a more objectively based field survey done by AAFC-PFRA in Saskatchewan between 1997 and 2002. However, it was perceived that the main reason for this discrepancy was that the Saskatchewan survey used a more restrictive definition of NT and RT. Nevertheless, there was still a significant degree of uncertainty regarding the validity of the Census data because it is based on a question that could create inaccuracy depending on varying interpretation by producer respondents.

The validity of these datasets was tested by utilizing additional information provided by the prairie weed surveys. These surveys also asked producers to record all field operations on

Table 2.5.7. Description and assessment of methodologies used to estimate NT and RT adoption levels for baseline assessment.

Source	Coverage	Year	Type	Specifics	Comments
Stats Can Census of Agriculture	All Producers In Canada	1996 2001	Questionnaire	Question 107: For the land seeded or to be seeded this spring, report the area of each of the following practices: include the area that was prepared last fall or this spring. -Tillage incorporating most of the crop residue into the soil. -Tillage that retains most of the crop residue on the surface (include minimum tillage) -NT seeding (include direct seeding into stubble or sod).	Accuracy of data is constrained by different interpretations of meanings by producers. NT is possibly overestimated since it allows for high disturbance direct seeding. On the other hand NT does not seem to allow a pre-seeding low disturbance operation to apply nutrients. RT is possibly overestimated since the leading question tends to ignore the impact of the seeding operation itself. On the other hand tillage that retains most of the crop residue is quite restrictive.
AAFC – PFRA	4000 Fields in Sask.	1997 to 2002	Annual field inspections	NT and RT assessed by soil disturbance indicators such as standing stubble, crop residue cover, row spacing, seed spread within row, and packing system. Key criteria for NT was 2/3 standing stubble. Key criteria for RT was the evidence of significant crop residue cover or any indication of some standing stubble. Definitions of NT and RT are significantly more restrictive than NCGAVS definitions used in protocol	Objective data improves accuracy, however, reliance on residue indicators creates underestimation of NT and RT under drought and low residue producing crops. This problem has been addressed by adjusting the values for these fields to reflect the same adoption pattern that has occurred on cereal stubbles on these same fields. Nevertheless, definition of NT and RT is still narrower than NCGAVS and therefore likely not suitable for protocols.
AAFC Weed Survey	Sask. – 740 Man. – 224 Alta. - 418	1995 1997 1997	Questionnaire	Question 11: What would you call your seeding system? _conventional, _ minimum tillage, _ direct seeding	Extremely subjective methodology since practices are not defined.
AAFC Weed Survey	Sask. – 740 Man. – 224 Alta. - 418 Sask. – 964 Man. – 371 Alta. - 702	1995 1997 1997 2003 2002 2001	Questionnaire	The questionnaire asks for detailed information on implements used on specific fields included in weed survey. The 2000's data is most detailed, but the 1990's is also quite specific. Since this database provides comprehensive records it is possible to assess tillage adoption rates using different tillage definitions.	This data set was used to test the validity of other data sets.

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surveyed fields. Therefore, it was possible to assess the tillage system on each field by prescribing an activity definition that was consistent with the actual field operations performed. The weed survey data was first analyzed using the restrictive tillage definition used in the Saskatchewan survey. This analysis resulted in lower adoption rate of NT and RT that was similar to the Saskatchewan survey. Secondly, the weed survey data was analyzed using the NCGAVS activity definitions. This analysis resulted in higher adoption rate of NT and RT that was similar to the Census of Agriculture data. These analyses increased the credibility of all data sets, but emphasized the need to know what activity definitions formed the basis for each data set. More importantly, this analysis provided the credibility required to be able to utilize the Census data for baseline analysis in this protocol.

A comparison of the Census and weed survey data using the NCGAVS definitions is provided in Table 2.5.8. There are some minor discrepancies that are probably due to smaller sampling sizes for some of the weed survey ecoregions, and the possibility of some interpolation errors. Both data sets have data from two time periods but these do not match up exactly as shown in Table 2.5.7. Therefore, a straight line interpolation was used. The rationale for using a straight line interpolation was based on the relatively straight line shown for a six consecutive year period in the PFRA Saskatchewan survey. (Haak, 2003).

When rolled up to the two NCGAVS regions the results are very similar, except for some discrepancy for RT in the Parkland region.

Table 2.5.8 Comparison of tillage system adoption in the Statistics Canada Census and the AAFC Weeds Survey datasets, interpolated to 1999, at the level of ecoregion by province and aggregated for the NCGAVS and protocol regions.

Percent Adoption	Interpolated 1999 Activity					
	NT		RT		FT	
	Census	Weeds	Census	Weeds	Census	Weeds
PARKLAND						
AB Black	15.57	11.35	29.59	18.90	54.84	59.60
AB Boreal Plain	8.44	4.35	18.82	11.05	72.74	75.60
AB Peace Low	9.82	8.85	23.80	21.80	66.37	69.35
MB Black	17.49	21.82	30.29	14.22	52.23	63.56
MB Boreal Plain	7.30	6.52	24.06	5.82	68.64	84.56
MB Boreal Shield	6.02	0.00	21.02	0.00	72.95	100.00
MB L. Man Plain	7.68	2.20	25.82	5.04	66.50	92.76
SK Black	19.76	22.45	30.86	26.05	48.85	46.40
SK Boreal Plain	14.52	25.75	28.39	15.50	57.09	54.05
TOTAL	**14.64**	**16.64**	**27.84**	**18.21**	**57.52**	**65.15**
Dry Prairie						
AB Brown	17.684	11.9	29.81	28.5	52.506	59.55
AB Dk Brown	18.664	10.9	36.9	45.75	44.44	43.3
SK Brown	26.586	25.05	27.202	25.55	46.212	48.6

SK Dk Brown	28.058	30.1	30.036	31.1	41.9	37.6
TOTAL	**24.49**	**22.67**	**30.04**	**31.20**	**45.47**	**46.13**

Note: Values in this table do not match Table 2.5.9 since these values report adoption based on percent of farms reporting. However, for comparison with Weed Survey this is appropriate since it uses a similar methodology.

It is also important to note that the Census of Agriculture data is also used for Canada's inventory reporting of GHG related to tillage systems. Therefore, in the absence of other more credible data sets, it was decided to utilize this data for protocol baseline assessment.

The Census of Agriculture tillage system adoption rates for 1996 and 2001 are shown in Table 2.5.9. These values reflect the proportion of land area reported in two questions, the first being the seeding question #107 provided in Table 2.5.7. The second question (#109) is the area of fallow land using chemical only, chemical and tillage, and tillage only for weed control. These three categories correspond to NT, RT, and FT tillage systems, respectively. The detailed calculation of the Census data is shown in Annex I. The straight line interpolated values for 1999 are used for the baseline assessment in this protocol.

Table 2.5.9 Interpolation of 1999 land area in NT, RT, and FT from 1996 and 2001 Census data (in percent of total seeded plus summerfallowed land area).

	NT			RT			FT		
	1996	2001	**1999** [1]	1996	2001	**1999**	1996	2001	**1999**
East	3.99	4.80	4.48	16.40	19.10	18.02	79.61	76.10	77.50
East-Central	14.96	20.72	18.42	20.92	20.81	20.85	64.12	58.46	60.72
Parkland	11.04	23.66	18.61	32.90	33.90	33.50	56.06	42.44	47.89
Dry Prairie	19.76	36.25	29.65	32.91	29.66	30.96	47.33	34.09	39.39
West	11.49	15.06	13.63	20.62	17.39	18.68	67.89	67.56	67.69

Note: [1] Interpolated 1999 value = 1996 value + [(2001 value – 1996 value) * 3/5]

2.5 (g) Generating Baseline Deductions from Tillage Adoption Data

The concept of a baseline deduction has been discussed in section 2.2 (a) and a simple example was provided. In reality the deduction calculation is made more complex because of the presence of three tillage systems, instead of two. Reduced till can be considered a partial change from full till, with no-till involving a more complete change. Since reduced till also contributes toward GHG emission reductions and removals it must also be considered in the baseline deduction.

The intent of the protocol is to establish net coefficients for NT, RT, and FT. All three of these are impacted by the current level of NT, RT, and FT adoption in the baseline. The equations

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used to calculate these net coefficients are as follows. This methodology preserves the integrity and principles explained more simply in section 2.2 (a).

Net NT coefficient = [Raw Coeff(FT to NT)*(%Area in FT)/100% + Raw Coeff(RT to NT)*(%Area in RT)/100%]

Net RT coefficient = [Raw Coeff(FT to RT)*(%Area in FT)/100% + Raw Coeff(NT to RT)*(%Area in NT)/100%]

Net FT coefficient = [Raw Coeff(RT to FT)*(100%Area in RT)/100% + Raw Coeff(NT to FT)*(%Area in NT)/100%

Table 2.5.10 provides the sum of all raw coefficients quantified earlier and presented previously in tables 2.5.2, 2.5.3, and 2.5.6. Using the baseline adoption rates provided in Table 2.5.9 and the above equations, net coefficients are provided in Table 2.5.11.

Table 2.5.10 Summary of Raw Coefficients associated with Tillage Changes

Region	Tillage Change	10 year SOC	N_2O	Energy	Total
East	FT to NT	0.25		0.1649	0.415
	FT to RT	0.20		0.1186	0.319
	RT to NT	0.08		0.0463	0.126
	NT to FT	-0.25		-0.1649	-0.415
	RT to FT	-0.20		-0.1186	-0.319
	NT to RT	-0.08		-0.0463	-0.126
East Central	FT to NT	0.41		0.1649	0.575
	FT to RT	0.16		0.1186	0.279
	RT to NT	0.26		0.0463	0.306
	NT to FT	-0.41		-0.1649	-0.575
	RT to FT	-0.16		-0.1186	-0.279
	NT to RT	-0.26		-0.0463	-0.306
Parkland	FT to NT	0.59	0.045	0.1091	0.744
	FT to RT	0.22	0.045	0.0239	0.289
	RT to NT	0.31	0.000	0.0852	0.395
	NT to FT	-0.59	-0.045	-0.1091	-0.744
	RT to FT	-0.22	-0.045	-0.0239	-0.289
	NT to RT	-0.31	0.000	-0.0852	-0.395
Dry Prairie	FT to NT	0.41	0.014	0.0589	0.482
	FT to RT	0.15	0.014	0.0250	0.189
	RT to NT	0.19	0.000	0.0339	0.224
	NT to FT	-0.41	-0.014	-0.0589	-0.482
	RT to FT	-0.15	-0.014	-0.0250	-0.189
	NT to RT	-0.19	0.000	-0.0339	-0.224
West	FT to NT	0.20		0.1091	0.309

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	FT to RT	0.03		0.0239	0.054
	RT to NT	0.16		0.0852	0.245
	NT to FT	-0.20		-0.1091	-0.309
	RT to FT	-0.03		-0.0239	-0.054
	NT to RT	-0.16		-0.0852	-0.245

Table 2.5.11 Net Coefficients for use in this Protocol (Mg CO_{2e} ha^{-1} yr^{-1})

Tillage System	East	East Central	Parkland	Dry Prairie	West
No-till	0.3443	0.4129	0.4886	0.2594	0.2550
Reduced till	0.2413	0.1127	0.0646	0.0079	0.0031
Full till	-0.0760	-0.1640	-0.2351	-0.2014	-0.0522

It is important to note that net coefficients for full till are negative and not zero. In the absence of a baseline they would be zero. In other words a negative FT coefficient reflects that there is already RT and NT in the baseline. Therefore the practice of FT at the project level reflects a reversal in practice from the baseline scenario, and therefore must be negative. For regions where the adoption of NT and RT is high, the size of the negative FT value is also larger.

This negative FT coefficient attributable to baseline condition is not the same as a reversal that occurs as a result of previously removed or sequestered soil organic carbon being lost due to a change to FT. This latter type of reversal is discussed in the next section.

2.5 (h) Reversals of Soil Organic Carbon

Section 193 of the Offset System Technical Background Document (2005) states that "*If there is a change in practice that could result in the release of carbon removed, the Proponent will calculate the reversal using a reversal factor set out in the protocol*".

It has already been established that the impact of a reversal of tillage practice change is the negative value of the original change. This impact is the same for all SSR's as already quantified and applied in the baseline deduction calculation.

However, there is an additional requirement to quantify not only the impact of not storing any new carbon in the current year, but the impact of losing previously sequestered carbon. The principle of equal but opposite impacts must also be applied to this previously stored carbon. One can state that the amount of previously stored carbon that would be lost by doing FT for one year would be equal to the carbon gained from doing NT for one year, assuming that the previous practice in the project was NT.

In order to calculate reversal coefficients for SOC change, one must first calculate net coefficients for positive tillage change. This is done by using the initial raw 10 year linear SOC coefficients from Table 2.5.10, the baseline adoption rates from Table 2.5.9 and the equations from section 2.5 (f). This essentially determines the component of the total net coefficient attributable to SOC gains. Only this is at risk to loss, since the other two SSR's (N_2O and energy consumption) are emission reductions not removals. One only needs to be concerned with ZT and RT coefficients for this purpose, since these are the only two that provide positive SOC gains which are reversible. Therefore, only the practice of FT can trigger a reversal, and the appropriate coefficient to use will depend if the previous practice in the project was NT or RT. If the reversal occurs on land that has a mixed history of NT and RT in the project, both coefficients must be used in a weighted approach that represents the proportion of NT and RT occurring. The reversal coefficients are shown in Table 2.5.12.

The detailed application with examples of how to use the reversal coefficients are provided in section 3.

Table 2.5.12 Net Reversal Coefficients to Quantify Losses of Previously Generated Soil Organic Carbon in the Project (Mg CO_{2e} ha^{-1} yr^{-1})

Region	Net SOC Coefficient		SOC Reversal Coefficient	
	NT	RT	Previous NT	Previous RT
East	0.2082	0.1514	-0.2082	-0.1514
East Central	0.3032	0.0493	-0.3032	-0.0493
Parkland	0.3864	0.0477	-0.3864	-0.0477
Dry Prairie	0.2203	0.0028	-0.2203	-0.0028
West	0.1653	0.0000	-0.1653	-0.0000

2.5 (i) Offset versus Temporary Offset Credits

The Offset System technical background document (2005) provides guidance for sink projects, where there is a risk of reversal of GHG removals. Projects issued offset credits are required to maintain these removals throughout a liability period, the length of which is not specified. During this time any reversals must be quantified and this must result in a reduction of offset credits issued or a replacement of previously issued offset credits.

Temporary credits are a mechanism whereby the project proponent can reduce project risk by not having to quantify reversals due to loss of soil organic carbon. However, this is balanced by significantly lower value of temporary credits when compared to offset credits.

Projects using temporary credits will exclusively utilize the net coefficients provided in Table 2.5.11. Projects using offset credits will utilize the net coefficients provided in Table 2.5.11 and the SOC reversal coefficients provided in Table 2.5.12. The coefficients in the latter table are only used for offset credit adjustments when there is a reversal event. For this protocol a reversal event occurs when the tillage activity is FT, instead of NT or RT. More guidance on which specific activities are deemed FT is provided in section 3.

For a project that never incurs reversals, the exact same coefficients (Mg CO_{2e} ha^{-1} yr^{-1}) and therefore the same number of credits are issued regardless if the proponent chooses offset versus temporary credits. The value of the credits is determined by the market place, with the offset credit providing significantly more value.

2.6 Management of Data Quality

Management of data quality is discussed extensively in section 3.

Detailing the Quantification Plan

Section III Quantification Plan

This section provides guidance to project proponents for monitoring and verification processes to accurately calculate GHG emission reductions and removals with an acceptable level of assurance as prescribed by the Offset System.

Deleted: Since the Offset System is designed to produce credits which are potentially recognized by the Kyoto protocol, there is a relatively high level of assurance required. ¶

The number of credits issued is calculated by simply multiplying the appropriate coefficient provided in section 2.5 by the number of hectares in NT, RT, or FT. Since the coefficients are based on specific activities, there are essentially three requirements for project proponents to generate credits using this protocol.

- determine and ensure specific land locations for inclusion in the project
- determine and ensure the area of land in hectares included for each specific land location
- determine and ensure the tillage activity (ie. NT, RT, or ZT) for specific time periods for all land area from specific land locations included in the project

This section provides specific guidance in these three areas. One of the challenges in designing technically based monitoring and verification requirements that are unique to the specific activities within this protocol, is recognizing that some requirements can be met through either a monitoring or a verification process, or both. There is some flexibility in designing these processes to achieve the acceptable level of assurance. In other words one proponent may choose a very rigorous monitoring program, which may reduce that amount of work required by an auditor or verifier. On the other hand a less rigorous monitoring program will require greater effort by the verification process to achieve the same level of assurance. This protocol allows for some flexibility, but provides a recommended approach that is intended to minimize cost.

The Offset System has stated that project proponents are also guided by ISO principles for quantification and verification of GHG emissions reductions or removals. ISO document 14064-3 provides specific guidance on verification and the Offset System is also developing more specific guidance on verification. Project proponents will be required to develop a monitoring and verification plan as part of their project proposal. Specific guidance for this plan that relates to this protocol is provided in this section.

Past scientific research on tillage systems has focused much more on quantification, than monitoring and verification requirements. Nevertheless, in recent history there have been a number of pilot projects and monitoring programs that form the basis for the guidelines provided in this section. These include tillage surveys conducted by the Prairie Farm Rehabilitation Administration (PFRA) Branch of Agriculture and Agri-Food Canada (Haak, 2003) and the Pilot Emissions Reductions, Removals, and Learnings (PERRL) initiative. The Soil Management Technical Working Group (SMTWG) has followed good practice guidance in consulting with tillage and annual crop system experts across Canada to identify and resolve a host of management scenarios and issues relating to tillage systems. Before outlining the specific monitoring and verification requirements it is important to more fully describe the activity definitions for NT, RT, and ZT.

3.1 Activity Definitions Developed for the Protocol

The fundamental variable in any tillage system impact on soil organic carbon is the degree of soil disturbance that occurs. Tillage definitions can be worded in a variety of ways and still mean essentially the same in terms of soil disturbance impacts. The definitions provided by the NCGAVS in the development of the SOC coefficients were provided in Table 2.5.7. These definitions require some adjustment for the protocol for two main reasons:

- Definitions must be worded so that project proponents and producers are able to definitively determine which set of specific field activities are eligible under these three tillage systems.
- Definitions must be worded so that the tillage systems can be accurately determined through monitoring and verification processes.

The adjusted tillage definitions as developed by the SMTWG are provided in Table 3.1.1.

Table 3.1.1 Definitions of tillage systems developed for this protocol

Region	Tillage System	Description
East	Full Till	More fall tillage than a single pass with HD cultivator [5]
	Reduced Till	One fall tillage with HD Cultivator, or < tillage
	No Till [2]	Up to two passes with low-disturbance openers (up to 33%) or 1 pass with a slightly higher disturbance opener (up to 40%) [3], discretionary tillage of up to 10% [4], no fall tillage

Important Caveat: This is a historical document; the scope of the proposed federal GHG offset system has not been finalized. This protocol was not approved by the federal government and may not reflect current federal policy decision.

East-Central	Full Till	More fall tillage than a single pass with a HD cultivator
	Reduced Till	One fall tillage With HD Cultivator, or < tillage
	No Till [2]	Up to two passes with low-disturbance openers (up to 33%) or 1 pass with a slightly higher disturbance opener (up to 40%) [3], discretionary tillage of up to 10% [4], no fall tillage
Parkland	Full Till	Fall Tillage > 40% [3] soil disturbance, > 2 cultivations on summerfallow.
	Reduced Till	Fall tillage limited to injection of manure or fertilizer with <40% [3] soil disturbance, 1 to 2 cultivations on summerfallow.
	No Till [2]	Up to two passes with low-disturbance openers (up to 33%) or 1 pass with a slightly higher disturbance opener (up to 40%)[3], discretionary tillage of up to 10%[4] , no cultivations on summerfallow, no fall tillage.
Dry Prairie	Full Till	Fall Tillage > 40% [3] soil disturbance, > 2 cultivations on summerfallow.
	Reduced Till	Fall tillage limited to injection of manure or fertilizer with < 40% [3] soil disturbance, 1 to 2 cultivations on summerfallow.
	No Till [2]	Up to two passes with low-disturbance openers (up to 33%) or 1 pass with a slightly higher disturbance opener (up to 40%)[3], discretionary tillage of up to 10%[4] , no cultivations on summerfallow, no fall tillage.
West [1]	Full Till	More fall tillage than a single pass with a HD
	Reduced Till	One fall tillage With HD Cultivator or < tillage.
	No Till [2]	Up to two passes with low-disturbance openers (up to 33%) or 1 pass with a slightly higher disturbance opener (up to 40%) [3], discretionary tillage of up to 10% [4], no fall tillage.

Notes:
1 The Peace River Lowland ecoregion is contained within the Parkland zone.
[2] Additional operations with harrows, packers, or similar non soil disturbing implements are accepted. Where a second low soil disturbance operation is performed it is normally for injection of fertilizer or manure.
[3] Percentage values associated with openers are based on average opener width (below ground) divided by row or shank spacing of the implement.
[4] Discretionary tillage of up to 10% means that up to 10% of the surface area of a single agricultural field may be cultivated to address specific management issues. These areas are determined on an annual basis, meaning that specific areas may change from year to year.
[5] A heavy duty cultivator or chisel plow is usually capable of primary tillage in annual crop stubble.

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3.2 Guidance on Specific Management Scenarios

Due to the complexity of annual cropping systems across Canada, additional guidance is required for a variety of management scenarios. These are addressed by topic below. It is important to remember that the objective is to determine the appropriate tillage system: NT, RT, or FT.

3.2 (a) Fall Seeded Crops

The definitions provided in Table 3.1.1 are applicable for spring seeded crops sown into fall harvested stubbles. These guidelines are also applicable for fall seeded crops, with the following added clarifications or exceptions. For fall seeded crops sown in the same year as the previous crop harvest, there will be a narrow window of time between these two events. The NT definition is based on this period of time. For this scenario In the Parkland and Dry Prairie region there is no RT option since the RT definition is only different from the NT in terms of the time of tillage not degree of soil disturbance, and this fall period has been eliminated.

For fall seeded crops seeded into fallow ground, the tillage system definitions associated with the fallow period remain the same. The only change is that the fallow period is significantly shortened.

The coefficients associated with the fall seeded crop are attributed to the year the crop is harvested not the year it is seeded. This prevents the occurrence of two annual credits provided in the same year.

3.2 (b) Perennial Forages in Rotation

Only annual crops are within the scope of this protocol, as explained in section 1.1 (a). However, this protocol includes tillage system in the year of establishment and termination of perennial forage that is grown in rotation with annual crops. Seeding of perennial crops into annual crop stubbles can be performed in either spring or fall. The same guidelines provided in Table 3.1.1 and section 3.2 (a) for spring and fall seeded annual crops also apply to seeding of perennial crops. For perennial crops seeded in fall, the tillage system coefficient is applied to the calendar year after seeding.

The termination of a perennial crop has an inherent tillage system, because producers will either use tillage or herbicides to terminate the crop. Therefore, assessment of tillage system must resume. While it is recognized that the formation of a dense sod layer under perennial forage may sometimes require tillage to allow for transition to annual cropping, the tillage definitions provided earlier still apply to this scenario. However, there are some further complexities depending on what time of year the termination occurs and when the subsequent annual crop is seeded. Three common scenarios are described in Table 3.2.1 and an interpretation on how to apply the tillage coefficients is provided.

Table 3.2.1 Rationalization of Coefficients for Termination of Perennial Forage

Scenario	Application of Coefficient
both perennial crop terminated and subsequent annual crop seeded in spring of the same year	apply coefficient for current year
perennial crop terminated in spring, field fallowed for remainder of year, subsequent annual crop seeded in fall or next spring	apply coefficients for two years, the first year as a fallow year, and the second year as a seeding year
Perennial crop terminated in late summer or early fall, subsequent crop seed in next spring	Apply coefficient for 1.5 years, the first year as a partial fallow year, and the second year as a seeding year. For the partial fallow year the coefficient should be reduced by one half

It is recognized that perennial forages provide significant GHG emission removal benefits through the enhanced sequestration of SOC in comparison to annual crops. It is more appropriate for these benefits to be quantified in a separate protocol for perennial forage. Nevertheless, a project utilizing both the tillage protocol and a perennial forage protocol could receive credits for both practices on the same parcel of land. It is anticipated that forage related benefits would start when the forage seeding is established and cease when the forage growth is terminated. There would be minimal overlapping occurrences where credits were being generated for two different practices at the same time. Therefore, for the scenarios provided in Table 3.2.1, one would possibly develop reduced forage coefficients to reflect that forage was only growing for part of one growing season.

Conceptually it is possible to have rotations with only perennial crops that are periodically reseeded with no annual crop in between. This reseeding traditionally has involved considerable tillage, and potentially could involve reduced till or no-till systems. This scenario is rare because most producers grow an annual crop for a few years before reseeding forages. Nevertheless, this scenario is outside the scope of this protocol.

3.2 (c) Irrigation

Investigations of carbon sequestration associated with irrigation are lacking, but the few studies available support the conclusion that irrigation increases SOC (cf Liebig *et al.* 2005). Irrigated soils in the Dry Prairie region are treated as Black/Grey soils by this protocol due to their significantly greater moisture availability to increase crop biomass and SOC. Irrigated areas in other regions are not treated differently since other regions for the most part have humid climates, which achieve lower increases in crop biomass and SOC through irrigation.

The irrigation coefficients for the Dry Prairie region are therefore the same as coefficients for the Parkland region. This also includes the same baseline deductions. While separate data to evaluate baseline on irrigated soils is lacking, it is assumed that adoption rates are similar to the Parkland due to similar growing conditions.

3.2 (d) No Crop Seeded and Crop Failures (eg. Flood, drought, hail)

While soil organic carbon is greatly enhanced by tillage system, crop biomass production that feeds inputs of crop residue and roots into the soil is imperative for SOC production and maintenance. Therefore, in years of drought, flooding, and other adverse climate related events the total carbon inputs and SOC gains can be greatly reduced or even negligible. Under a customized protocol approach these occurrences may have to be dealt with separately and quantified. However, under this default protocol these events can be ignored. In other words the same NT, RT, and FT coefficients are applied regardless of the actual soil carbon produced by crops in individual years. The essential reason for this conclusion is that the coefficients relating to SOC gain developed in the Century 4.0 model for the NCCGAVS already account for these climate related impacts.

However, the impact of adverse climate may force a producer to adjust management. A crop failure may impact the ability to adhere to the tillage definitions provided in the protocol, if a producer resorts to tillage management after the crop failure. Table 3.2.2 provides some scenarios and guidance for the application of coefficients for each of these scenarios.

Table 3.2.2 Rationalization of Coefficients for Adverse Climate Events

Scenario	Application of Coefficient
crop failure early in growing season, crop is reseeded	allowance for one more low disturbance operation for reseeding operation to meet the definition of NT
crop failure early in growing season or no crop seeded due to excess moisture, fallow for remainder of year	use definitions from Table 3.1.1 for spring seeded crops and subsequent fallow management to determine tillage system
crop failure early in growing season, cover crop or green manure [1] seeded mid way through growing season	allowance for one more low disturbance operation for seeding cover crop, to meet the definition of NT
no crop seeded due to excess moisture, cover crop or green manure [1] seeded mid way through growing season	use definitions from Table 3.1.1, ie. up to 2 low disturbance operations between previous harvest and seeding of cover crop

Note: [1] If tillage is used to incorporate a cover crop or green manure the definitions provided in Table 3.1.1 must be applied, and may result in a FT or RT designation.

3.2 (e) Crop Utilization and Residue Management Scenarios

A variety of practices related to the utilization of crops and residue by livestock can potentially impact carbon inputs into the soil. These include the following:

- grazing of crop residues, including chaff piles by livestock
- baling of straw residue or collection of chaff for offsite feeding to livestock

- harvesting of total above ground biomass from annual crops (ie. hay, silage or greenfeed) as feed for livestock.
- grazing of standing or swathed vegetation from annual crops.

In all of these practices much of the crop carbon is recycled back to the soil as manure, either directly by grazing livestock or by spreading farmyard manure back on to the land As a result grazing or feeding of crop biomass and residues to livestock has been shown to have a small impact on SOC change. (cf Liebig *et al.* 2005). Therefore, these practices are permitted under this protocol. However, any secondary impacts that these practices may have on tillage practices must be accounted for through adherence to the tillage definitions provided in Table 3.1.1.

3.2 (f) Burning Crop Residues

Excess crop residues are sometimes a greater obstacle to overcome for low disturbance seeding operations. In other words, tillage has traditionally been used to bury excess crop residue and enable good seed to soil contact during seeding. However, technological advancements have improved the trash clearance capabilities of modern seeding equipment. Nevertheless, certain crop residue types, such as flax, remain a challenge for producers. Flax straw has limited value as a baled product, so therefore some producers resort to burning flax straw swaths after harvest.

While burning results in immediate GHG emissions of CO_2, there is no evidence that occasional swath burning results in lower SOC gains. (Liebig *et al.* 2005). This is likely due to the relatively low proportion of biomass production in a typical crop rotation that can be attributed to burned flax swaths. Therefore, the practice of burning flax swaths does not impact this protocol.

3.2 (g) Management of Annual Row Crops

Management of annual row crops, such as corn, often utilize inter row tillage to control weeds. However, in most regions herbicides are effective in replacing tillage for weed control. Therefore, the occurrence of inter row tillage during the growing season results in the land being deemed as FT.

3.2 (h) Manure Management Scenarios

Addition of livestock manure to agricultural land can enhance SOC in two ways, first through the addition of crop nutrients that stimulate crop growth and biomass production, and second through the addition of organic inputs directly into the soil. The first mechanism is essentially the same as the addition of commercial fertilizer sources. The magnitude of the second mechanism varies greatly, depending on the organic content of the manure source. As a general rule liquid or semi solid manure sources contribute minimally to direct carbon inputs, however, solid manure can provide significant inputs.

Nevertheless, both of these mechanisms for positive SOC change are not quantified in this protocol. As already discussed the impact of nutrients is relatively independent of tillage system and beyond the scope of this protocol, but could be addressed in a separate nutrient management protocol. Also, as already discussed, the issue of organic inputs is considered part of the normal cycling of carbon within a farm operation. For this protocol, it is assumed that for the two main farming systems applicable to this protocol, namely grain production and livestock production, the outputs and inputs of carbon sources impacting SOC are relatively stable and independent of tillage system. Nevertheless, it is recognized that for a customized approach to quantifying SOC change it may be more important to document and account for carbon inputs and outputs, especially if these customized protocols utilize a soil carbon measurement approach for quantification.

Therefore, under this protocol the application of various manure sources is permitted. However, if the application of this manure involves incorporation that exceeds the allowable limit of soil disturbance prescribed for NT and RT, then this will impact ability to adhere to activity definitions. This may be perceived as a conflict with other best management recommendations, since incorporation of manures (especially solid) is recommended from a nutrient management perspective. If incorporation of manure is a significant practice producers may be advised to not participate in this protocol, but may still benefit from GHG emissions reduction/removals through participation in a nutrient management protocol or SOC protocol utilizing a customized approach.

3.3 Monitoring and Verification of Tillage System Activities and Land Parcels

A number of potential methods can be used for monitoring and verifying tillage system activities. The key to any activity is to be able to determine and ensure the tillage system as NT, RT, and ZT. These methods are listed and described in the following subsections, and presented in order from lowest to highest, in terms of their ability to provide a high level of assurance.

3.3 (a) Signed Producer Contract (Sworn Affadavit) With No Field Activity Records

Under this scenario each land manager is provided with a contract which provides the tillage definition requirements as presented in section 3. The producer reads the contract, completes and signs a form, and returns it to the project proponent. This form would contain a table with the following information:

- legal land description
- size of land parcel
- tillage system
- year

Each row on the table would be required to record each unique combination of values for that farm. For example, for a given legal land description there may be more than one land parcel or field, more than one tillage system per parcel, and differences in tillage system between years. While this methodology provides the necessary data to make an offset credit calculation for a farm, it has a low level of assurance since it is requires the producer to make an assessment of tillage system without disclosing specific details of tillage practices. This methodology is not considered acceptable for this protocol.

3.3 (b) Signed Producer Contract (Sworn Affadavit) With Specific Field Activity Records

This scenario is similar to the previous one, except the land manager records the specific type and date of all field operations on specific land parcels enrolled in the project. Normally a separate form is used for each agricultural field and each year to be able to document differences between fields and years. If differences exist within one field separate forms may be used for separate parcels within one field. This method is considerably more acceptable since it requires the project proponent and / or third party auditor rather than the individual farm producer to objectively analyze all field operations on all land parcels to ensure compliance with tillage definitions. It is anticipated that due to the relatively low value to individual farm producers, most projects will involve pools of many farmers. The project proponent will utilize trained staff and computer database systems to more cost effectively record and analyze data to determine tillage system.

This protocol requires that this methodology be used as the primary monitoring tool to calculate emission reduction and removals. This needs to be done for all land parcels for all years that credits are issued for in the project. The rationale for including 100% of lands 100% of the time is due to the potential temporal and spatial variability in tillage practices.

It is recommended that this type of monitoring program also continue after the crediting period throughout the liability period, but not on 100% of fields 100% of the time. Due to the uncertainty of the length of the liability period, it is not possible to recommend what percentage of land should be monitored, and how often during this period.

A sample field record sheet is shown in Table 3.6.1 as part of the example discussion provided in section 3.6.

3.3 (c) The Potential for Analysis of Tillage Systems through Remote Sensing Techniques

A number of researchers have investigated the potential to use satellite imagery together with computer image classification techniques to characterize various landscape and surface features. Of greatest applicability for this protocol is the progress made to estimate the amount of crop residue cover and degree of surface roughness (McNairn, 2005).

An analysis of this work for use in this protocol was conducted by the SMTWG. Crop residue cover and surface roughness are important indicators for soil erosion control, however, they have limited applicability for assessing tillage systems as defined by this protocol.

Surface roughness is related mainly to the primary or first tillage operation that occurs after harvest, due to its outcome of increased surface roughness. Generally, a mouldboard plough will create more soil disturbance and surface roughness than a heavy duty cultivator. Therefore, one could potentially use remote sensing to distinguish between RT and FT in eastern regions, associated with primary tillage operations that often occur in late fall. However, the key factor impacting surface roughness for all tillage systems is the packing system design on the seeding implement. Packing system design impacts on surface roughness vary greatly within tillage systems. Therefore, surface roughness cannot be used to distinguish NT from RT or NT from FT.

Crop residue amount is more closely related to tillage system, since residue is buried and progressively breaks down as tillage increases. However, a more important attribute of crop residue for tillage system verification (especially NT) is the stubble portion. The stubble portion is defined as the standing and anchored portion of crop residue that is below the harvest cutter bar and which does not pass through the combine or harvesting machine. The degree to which stubble remains standing or anchored to the soil is a much better indicator of soil disturbance and tillage system. Crop residue cover amount may have potential use to distinguish NT from FT. However, it will be less likely to distinguish NT from RT. For example, some RT systems that use minimal tillage may in fact achieve greater crop residue cover than NT, due to the flattening of standing stubble which is thus more detectable from remote sensing.

Therefore, while technological improvements could change the current analysis, remote sensing is not currently considered a viable option for monitoring or verifying tillage systems for this protocol.

3.3 (d) External Data Sources to Monitor or Verify Land Parcels and Locations

The size of land parcels is obviously required to calculate the size of the offset credit. The specific location of land parcels is required to ensure that there is no duplication of credits issued to the same land parcels for the same time period. In addition to the legal land descriptions and land parcel sizes provided by the producer on field record sheets, there are a number of other data sources which increase assurance of location and size. These include the following:

- georeferenced aerial photo or satellite image
- crop insurance data for annual cropland
- municipal assessment data
- on site GPS coordinates

It is recommended that at least one external data source be utilized for 5 to 15% of project fields. The specific percentage will depend primarily on who collects this data and if this is done through a monitoring versus a verification approach. For example, GPS coordinates provided by a producer would require a higher percentage, than aerial photos acquired and analyzed by the project proponent. A data source acquired and analyzed by the project proponent would require a higher percentage than if this data was acquired and analyzed by a third party auditor.

It is assumed that these activities will often be more costly to perform under a verification process than a monitoring process. It is also anticipated that an auditor may desire to repeat all elements of a monitoring process to a limited extent to verify the process's validity. Therefore, it is assumed that all projects will address the issue of legal land description and size of land parcels through both a monitoring and verification process plan.

It is recommended that a blended approach of targeting and random selection be used to identify specific sites for more detailed monitoring. Some computer based analysis of legal land location and land parcel size could be undertaken as follows:

- identify duplicate legal land parcels applying for credits, either within one farm or when considering all farms within a project.
- Identify land parcels that exceed allowable limits. For example, it is known that a quarter section does normally not exceed 65 hectares.

It is expected that the above computer analysis would be performed on 100% of sites based on information provided in field record sheets.

Legal land locations and parcels with potential problems should be targeted, but random selection processes should also be used if additional sites are required to meet the required percentage.

3.3 (e) External Data Sources to Monitor or Verify Tillage System

Processes for monitoring and verification of tillage system activity have been developed by PFRA (Haak, 2003), and the PERRL pilot project. These processes are based on a field inspection assessment, and involve a number of readily observable features that remain visible for a certain period of time after the tillage activity occurred. Field inspections only need to be conducted to monitor or verify NT or RT activity. Disclosed FT activity does not require assessment, unless an individual producer appeals this determination by the project proponent from the detailed field record sheet.

The percentage of project fields recommended for more detailed tillage activity assessment is also 5 – 15%, and governed primarily by who collects the data, and if it is done through a monitoring versus a verification approach. Therefore, a blended monitoring and verification approach is also anticipated for verifying tillage system, as explained in the previous section.

However, the issue of targeting and site selection is more complex for tillage system activity, and is discussed in section 3.3 (e.v).

3.3 (e.i) Equipment Inspection

One of the most easily observable features are the field implements used in crop production, namely, seeding implement(s), manure or fertilizer applicator, and tillage equipment. With each of these implements two key measurements are the row or shank spacing, and the width of the opener that penetrates the soil surface. The opener width divided by the row or shank spacing provides the percentage soil disturbance resulting from a single pass with this machine. This data can be compared with the soil disturbance definitions provided in Table 3.1.1. If any of these implements do not comply with the definition, and the producer has confirmed the use of these implements on specific land parcels through followup communication, then these parcels should be excluded from the project.

If all of these implements do comply with the definition there is some evidence that the asserted tillage activity did take place. If the producer can provide an invoice of the equipment purchase there is additional evidence that the specified activities took place on specific land locations. However, because this cannot be 100% guaranteed (without having been present on location when the activity is done) it is necessary to consider some post activity indicators or evidence of tillage system activity that can be readily observed in the field itself (see next section).

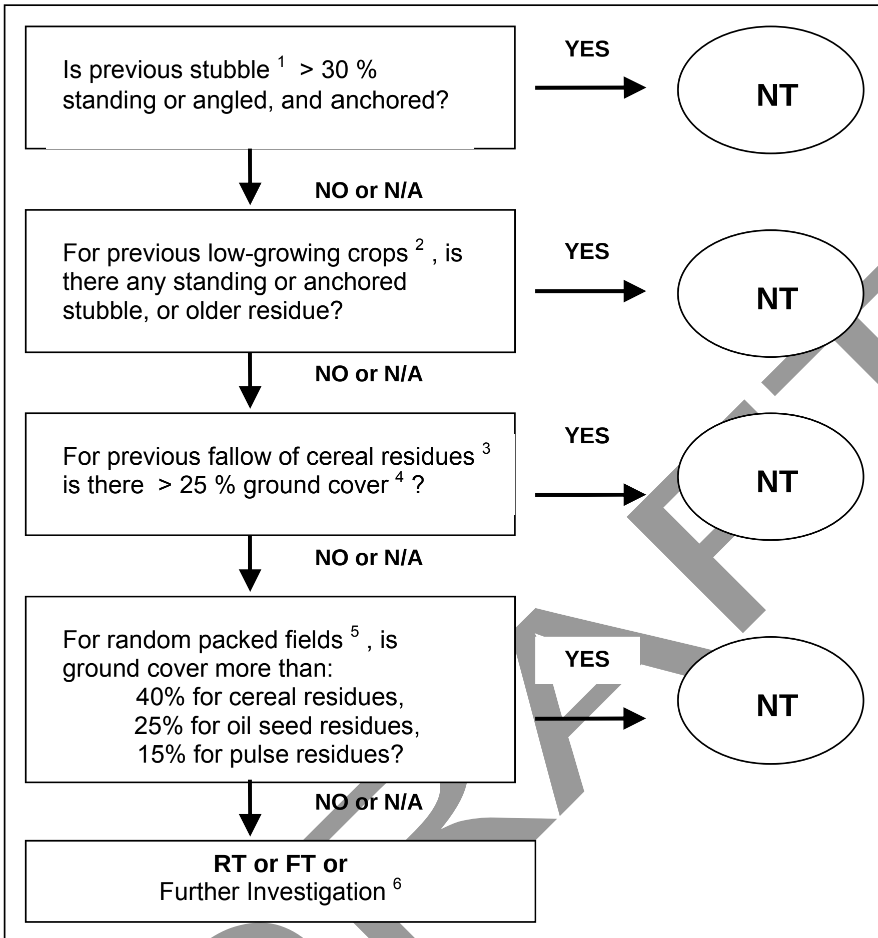
Finally, it is also useful to observe packing system equipment for comparison with field record sheet and followup field inspection to ensure consistency.

3.3 (e.ii) Spring Field Inspection To Assess NT Seeded Fields

For NT activity, the most suitable time to do this field assessment is in late spring, after the newly seeded crop has emerged but before the new crop canopy has established to point that it masks the key features that need to be assessed (eg. previous crop residue). The first step in assessment is to confirm that the row spacing and plant spread within the row are consistent with the row spacing and opener type observed on the seeding implement and recorded in the field record sheet.

The next step is using the flowchart provided in Figure 3.3.1 to more objectively assess soil disturbance that is consistent with the definitions provided in Table 3.1.1.

Figure 3.3.1 Decision Support Tool to Assess NT after Seeding



Source: Adapted from PERRL by SMTWG

Figure 3.3.1 Notes

[1] **Stubble -** Stubble is defined as the portion of crop residue that remains standing and anchored to the soil immediately after harvest. Being anchored means that the stubble is firmly attached to root systems that have not been disrupted by soil disturbance. As the soil is disturbed through tillage stubble tends to flatten and become unanchored.

[2] **Low growing crops** – Low growing crops, such as pulses, must be cut close to the ground at harvest. As a result the stubble is very short and hard to recognize. These crop residues also tend to decompose more quickly. Under no tillage considerable standing stubble is usually present, but requires more careful inspection to recognize. Also, under no tillage systems one can usually find some older residue from a higher residue

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producing crop that was grown before the low growing one. The absence of these two criteria would suggest conventional tillage.

[3] **Crops seeded after fallow** – Often the stubble condition after seeding of previously fallow fields will be flat, even if the fallow field was not tilled (i.e. chemfallow) and no till seeded. That's because the stubble has weakened considerably due to weathering and is easily flattened even with low disturbance. Usually the type of crop residue that is fallowed is cereals. If the residue was oilseed or pulse it will be almost impossible to determine the tillage system. Another option may be to inspect fallow fields in the previous fall to better assess fallow management.

[4] **Ground Cover** – Ground cover refers to the percent of soil surface covered by crop residue. This is a visual estimation, however, various tools can be used to assist in calibrating oneself in doing these measurements. The first is to use photographs with known amounts of crop residue ground cover. The second is to use a rope with distinct markings at regular intervals along the rope. This rope is stretched out in the field perpendicular to the most recent field operation. The percent ground cover is equal to the percent occurrence of crop residue intersection below each point along the rope

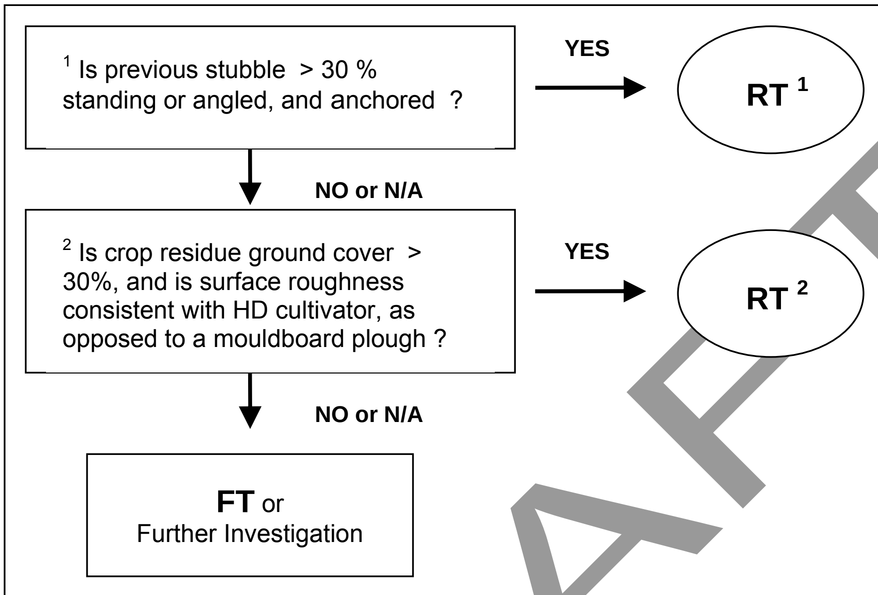
[5] ***Fields that are Random Packed*** - Random packing with harrows, coil packers, or rollers to smooth fields will always tend to flatten stubble. As shown in Table 3.1.1 these fields can meet the requirements of no tillage if there was little soil disturbance through previous tillage and seeding operations. . Random packing is normally easily recognized through a field inspection. If random packing is confirmed and the stubble is flat, one needs to rely more on the amount of residue or ground cover that is present. While ground cover can vary significantly depending on field and growing conditions, some general residue amounts for conventional and zero tillage can be used, as shown in the table.

[6] **Further Investigation** There may be other factors that may impact key features such as stubble and crop residue cover. These could include some of the scenarios discussed in section 3.2.

3.3 (e.iii) Field Inspection To Assess RT

As per Table 3.1.1 RT is essentially defined based on fall management after crop harvest. Therefore, a field inspection is most suitably conducted in late fall (after all field operations have ceased) or in early spring (before new year field operations commence). This can be challenging as a very narrow window of opportunity exists just before winter snowfall or immediately after spring snowmelt. However, since the RT coefficient is extremely low, there will likely be very few occurrences of RT, and relatively few sites to inspect. The criteria for assessment is shown in Figure 3.3.2.

Figure 3.3.2 Decision Support Tool to Assess RT in Late Fall / Early Spring



Source: SMTWG

Figure 3.3.2 Notes

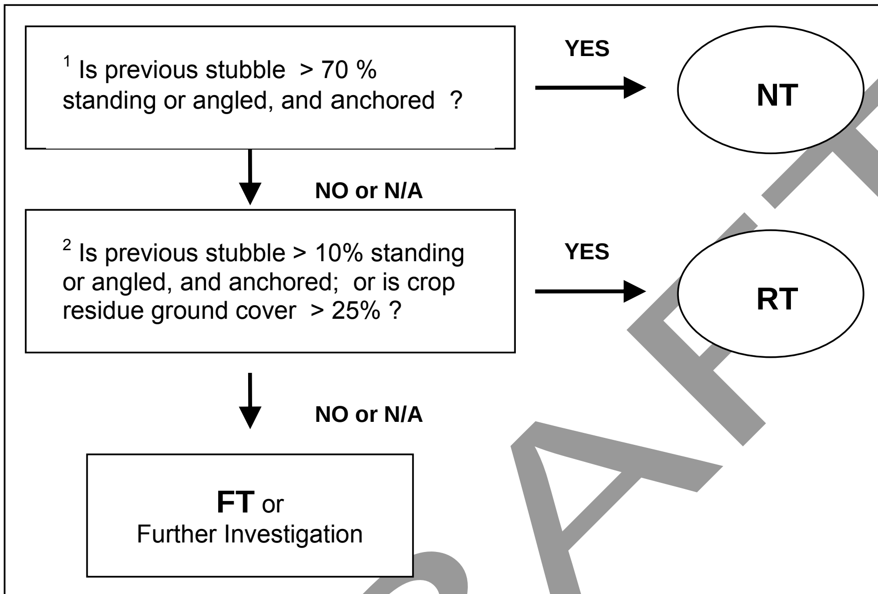
[1] The first box is used to assess RT in the Dry Prairie and Parkland regions only. This is based on the assumption that soil disturbance equivalent to or more than a single pass with a heavy duty cultivator would cause > 40% soil disturbance and would be deemed as FT.

[2] The second box is used to assess RT in the East, East-Central, and West regions only. This is based on the assumption that soil disturbance equivalent or less than a single pass with a heavy duty cultivator would result in at least 30% crop residue ground cover, and that a single pass with a mouldboard plough would result in less than 30% ground cover. The surface roughness pattern of a mouldboard plough will normally be highly rough overturned lumps in a linear rows having a width equivalent to the width of each plough tool. The degree of roughness for HD cultivators will be slightly to moderately high depending on the presence of mounted harrows and a pattern of valleys and ridges will be consistent with the shank spacing and opener width of the cultivator shovels.

3.3 (e.iv) Field Inspection To Assess Fallow Management

Assessing fallow management is most suitably done in mid to late fall, after the last killing frost. One can assume that after this time period there is no further need for tillage to control weeds. The criteria for assessment is shown in Figure 3.3.3.

Figure 3.3.2 Decision Support Tool to Assess RT in Late Fall / Early Spring



Source: SMTWG

Figure 3.3.3 Notes

[1] Up to 30% standing stubble may become flattened and possibly unanchored from wheel track compaction during harvesting and spraying, hail, and natural weathering.

[2] Distinguishing between RT and FT based on more than 2 fallow operations can be difficult depending on a variety of factors such as previous crop type, biomass production, and fallow weather conditions. The values in this figure are ballpark estimates that may not be accurate in all cases. Therefore, there may be a need for further investigation and some flexibility of these criteria based on local conditions.

3.3 (e.v) Challenges for Tillage System Field Assessment

A major constraint for field assessment of tillage system is the extremely narrow time window between when activities are undertaken and when monitoring or verification activities need to take place. For example, the completion of NT activities occurs when the crop is seeded, and field inspection assessment for NT is normally conducted about two weeks thereafter.

Important Caveat: This is a historical document; the scope of the proposed federal GHG offset system has not been finalized. This protocol was not approved by the federal government and may not reflect current federal policy decision.

Therefore, it is not feasible to collect field operation records (as described in section 3.3 (b)) in advance of conducting field assessment work.

Ideally, it would be advantageous to have field records data in advance for several reasons:

- to make more accurate assessments based on having more information on the activity.
- to be able to use a targeted approach for site selection for field assessment.

The latter bullet would involve doing some analysis of field record data to flag potential problem sites, similar to that presented in section 3.3 (d). In this case one would flag sites where the specific activities undertaken by producers would suggest that their tillage system was near the border line between NT and RT, or RT and FT.

Therefore, it is not possible to utilize this type of targeting, at least in the first year of a project. However, because it is anticipated that most projects will be multiyear, one can begin targeting in year two, based on field operations from year one.

Other criteria also need to be considered in selecting sites for tillage activity monitoring or verification. The principle of representativeness should be used to ensure that all regions are included. At the same time some regions or local areas may also require targeting, especially if weather related events impact the ability of producers to implement tillage activities. Finally, an element of randomness must also be maintained so that producers are not able to guess if they have been chosen for additional monitoring or verification. Consistent with this principle is the need to not exclude previously monitored/verified sites, from the pool of sites that are considered for future monitoring/verification. Also, sites should be selected on an annual basis, that is, no sites should be preselected for multiyear monitoring.

Nevertheless, challenges remain on conducting monitoring and verification activities in a timely fashion. This is addressed more fully in the next section.

3.4 Planning for Effective Monitoring and Verification

Due to the challenges raised in section 3.3 (e.v), it is recommended that data be collected from agricultural producers two times per year. The first collection period, mid to late winter, is essentially an application form where a producer indicates intention to practice NT or RT on specific land parcels, provides parcel sizes and legal locations. Also, included would be the previous crop type, yield, and other management practices conducted since the previous harvest (see items listed in section 3.2.). This information would be available for monitoring and verification processes that occur later in the same year.

The second data collection point would be in late fall where a producer records all pertinent field operations that occurred during the just completed crop year on project land parcels. This information is compared with other monitoring and verification data collected earlier in the year.

A full year of project implementation activities, including the above processes is described in Table 3.4.1. While there may be opportunities to adjust these activities, these recommendations strive to minimize administrative cost while at the same time ensure adherence to ISO principles for monitoring and verification of GHG assertions.

Table 3.4.1 Annual Tillage Protocol Project Activities

Activity	Date	Responsibility	Description
Producer Application	February	Producer	Intention to NT or RT on specific parcels, providing parcel size and legal location, also provide data on previous crop type, yield, and other management since harvest
Application Processing	March	Project Proponent	Computer data entry, basic computer analysis to ensure eligibility of land based on parcel size limits, and no duplication of legal land locations, approval notification for sites not requiring additional monitoring
Monitoring & Verification of Land Locations [1]	March	Project Proponent, Auditor	Selection of sites, acquisition and analysis of external land parcel data sources suitable for in office assessment
Application Processing	April	Project Proponent	Approval notification for sites requiring additional monitoring from previous step
Implementation of NT or RT Practices	April to October	Producer	Implementation of crop management involving desired NT or RT activities on approved land parcels, maintain record of field operations
Monitoring & Verification of NT Practice	May to June	Project Proponent, Auditor	Site selection for field assessment of NT practices, conduct monitoring & verification of NT (see guidance in sections 3.3 e i, ii, v)
Monitoring & Verification of RT & Fallow Practice	October to November	Project Proponent, Auditor	Site selection for field assessment of RT and fallow practices, conduct monitoring & verification of RT and fallow (see guidance in sections 3.3 e i, iii, iv, v)
Producer Field Record Sheets	November	Producer	Completion and submission of detailed field record sheets for each land parcel
Monitoring & Verification of NT, RT, & Fallow Practice	December	Project Proponent, Auditor	Comparison of field assessment data with field record sheet data submitted by producer to ensure consistency, resolution of outstanding issues through follow up

			communication with producer
Credit Calculation	January	Project Proponent	Determination of tillage system from field record sheet data, application of appropriate coefficients and calculation of offset or temporary credits for specific land parcels
Final Verification	February	Auditor	Verification of tillage system determination and credit calculations
Credit Issuance	March	Project Proponent	Offset or temporary credits issued to producers

Notes: [1] Monitoring & verification of land locations can alternatively be carried out as part of the field assessment that takes place in June for NT activities or in late fall for RT and fallow management. In this scenario GPS coordinate measurements could be obtained as an external data source.

It is likely that a blended approach of both in office and field assessment processes have merit, for the following reasons:

- external data sources that involve in office assessment (eg. aerial photos) are required to resolve land parcel eligibility issues to enable timely approval of applications before the field season begins
- some reliance on external data is required to conduct field assessments for tillage activity, for the simple reason that one needs to use maps and photos to find and confirm the legal location of specific land parcels.

For the above reasons, it is recommended that most sites selected for monitoring or verification of legal land locations and parcel size will be the same locations that are assessed for tillage activity through a field inspection.

3.5 Management of Data Quality

Management of data quality is enhanced through the utilization of computer technology and computer based analysis. In addition to the specific applications already mentioned, it is recommended that a GIS based data management system be used. This is particularly useful for the following scenarios:

- defining specific land parcels or fields that occupy more than one land location,
- defining multiple land parcels or fields on the same legal land location,
- defining irregular shaped land parcels using GPS coordinate derived polygon boundaries
- keeping track of specific tillage activities on sub parcels within larger parcels (see section 3.7)

Standard data quality management protocols are also recommended including regular backup databases and password protection. It is advantageous if third party auditors have capability and access to utilize the same data management functions as the project proponent, for verification tasks that involve repeating some of the same tasks carried out by the project proponent.

3.6 Sample Calculations

As already mentioned the essential quantitative ingredients in implementing projects under this protocol are:

- determine and ensure the area and legal location of specific land parcels for inclusion in the project
- ensure the tillage activity (ie. NT, RT, or ZT) for specific time periods for specific land parcels
- calculate the offset or temporary credit by multiplying the area of a given land parcel by the appropriate coefficient that accurately represents the tillage activity on that land parcel

While sample calculations could be provided for each of these steps, and for various scenarios under each step, this protocol provides two types of sample calculations that address the more complex technical issues of interpreting activity definition, calculating offset credits, and making adjustments for reversals.

3.6 (a) Interpreting Activity Definitions and Eligible Land Areas from Field Record Sheets

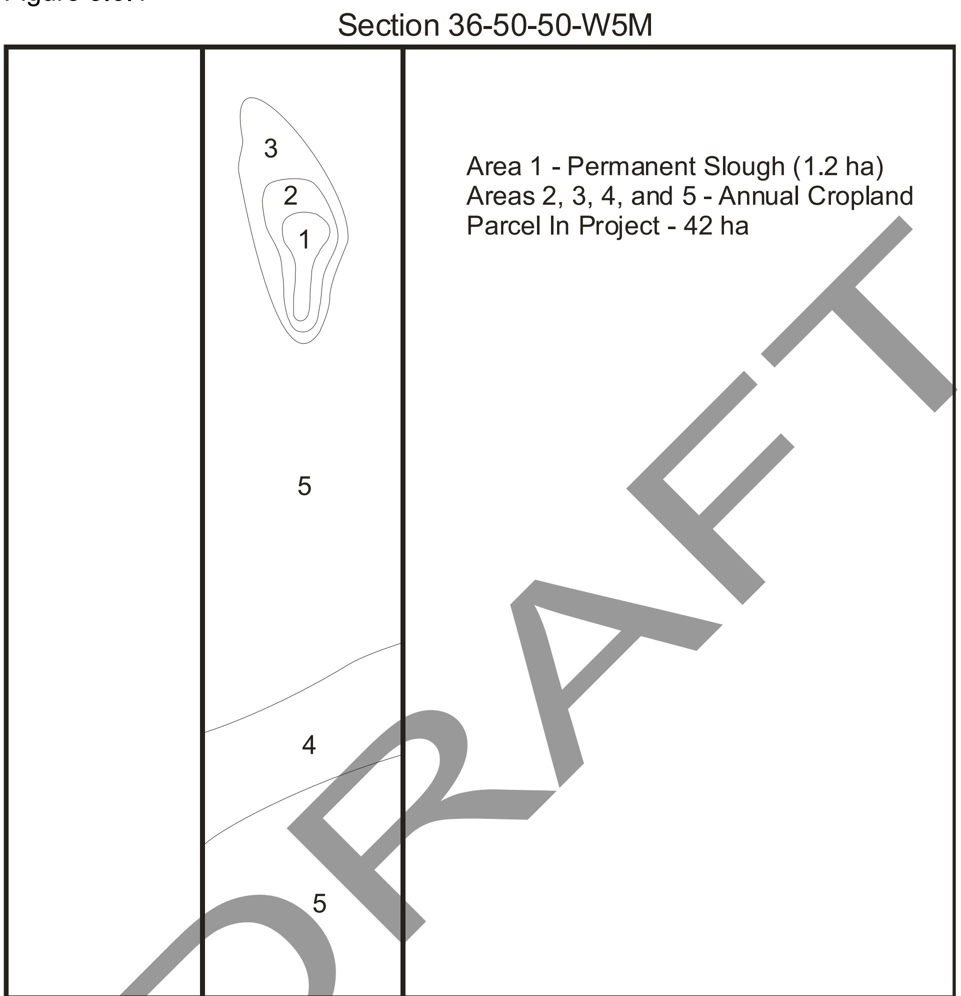
Table 3.6.1 provides an example of a field record sheet from one land parcel in one year. Most examples will likely be less complex than the one provided here, however, this example illustrates one acceptable way how these complexities can be addressed. Attached to this example form is a map (see Figure 3.6.1) which shows specific management sub areas within the land parcel within the legal land description. Assume for this example that the land parcel is located in the Parkland region.

Table 3.6.1 Field Record Sheet Example

Producer Name **John N. Till**						
Legal Land Description of Parcel or Field **West Half-36-50-50-W5**						
Size of Parcel in Project (hectares) **42 (103.8 acres)** Note: if parcel does not occupy entire legal land description draw on the map below the boundary of the parcel within land description						
Record all field operations that involve mechanical contact with soil, other than wheel traffic (ie. tillage, seeding, fertilizer/manure/lime injection/incorporation, harrowing, rolling etc.). Record date, shank/row spacing, opener width (portion that penetrates soil), and area in hectares. If a specific operation involved only a portion of the parcel, then draw this portion on the map provided below, and label the sub area on both the map and this form. Also indicate the reason for doing the operation on only a portion of the parcel or field.						
Date	Implement Type	Reason	Shank/Row Spacing	Opener Width	Area (ha)	Sub Areas #
10/3/06	Fertilizer Injection	Sub area #2 too wet	16 in.	4 in.	40	3,4,5
5/10/07	Tillage of Weed Patch	Foxtail barley seedlings from blown in seed from neighbour's land	12 in.	16 in.	5	4
5/15/07	Air Drill	Sub area #2 and #3 too wet to seed	9 in.	2 in.	36	4,5
5/26/07	Tillage of depressional wet areas	Weed control after soil dried up	12 in.	16 in.	6	2,3
5/31/07	Air Drill	Delayed seeding from wetness	9 in.	2 in.	6	2,3

10/8/07	Fertilizer Injection		16 in.	4 in.	42	2,3,4,5

Figure 3.6.1



Assuming this is the first year of this project the land eligible for credits can be calculated in the following steps:

1. The offset credit for the 2007 calendar year is determined by practices that occur between harvest 2006 and harvest 2007. Therefore, all of the practices in Table 3.6.1 fit this time period, except for the final fertilizer injection on October 8, 2007. This latter practice will be considered in the future with subsequent practices for the 2008 crediting period.

2. The area of land in hectares for each sub area can be calculated from data in Table 3.6.1 and Figure 3.6.1 as follows: #1 - 1.2, #2 – 2, #3 – 4, #4 – 5, and #5 – 31. Sub area is excluded from the project because it is a permanent slough.

3. Comparison of data in Table 3.6.1 with tillage system definitions provided in Table 3.1.1 reveal that tillage system in sub area #5 is NT, since both operations have less than 33% soil disturbance (ie. fertilizer injection: 4 / 16 = 25% and air drill 2 / 9 = 22%).

4. For sub areas #2, 3, and 4 which total 11 hectares, 4.2 of these qualify as NT due to the 10% allowance for discretionary tillage. The remaining 6.8 hectares are designated as RT since none of these areas have 40% or more soil disturbance in fall. Therefore, the total hectares designated as NT and RT for this land parcel are 35.2 and 6.8 hectares, respectively.

5. Therefore the offset or temporary credits issued for this land parcel for 2007 are calculated using coefficients from Table 2.5.11, as follows:

   (0.4886 * 35.2) = (0.0646 * 6.8) = 17.64 Mg $CO_{2\ equiv}$

3.6 (b) Impact of Reversals on Offset Credit Calculations

Reversals will not only be tracked and resolved at the project level, but also at the producer level. This will ensure that reversals are essentially paid for by the party responsible for their occurrence. In other words project proponents will likely not spread the cost of reversal caused by a few individuals among all participants in the project.

Table 3.6.2 provides an example for a farm for the entire life of the project. Following this example is a discussion on implications of changing land in the project and whether this type of example should be tied to individual land parcels rather than a whole farm. There is also further discussion on the implications of this example for permanent versus temporary offset credits.

This example uses the following assumptions:

1. The land is located in the Parkland region, therefore, the appropriate coefficients are as follows:
   - NT coefficient: 0.4886 **(Q)**
   - RT coefficient: 0.0646 **(R)**
   - FT coefficient: -0.2351 **(S)**
   - Reversal SOC coefficient for previous NT: -0.3864 **(T)**
   - Reversal SOC coefficient for previous RT: -0.0477 **(U)**

2. The total land from this farm in the project is 1000 hectares and does not change during the life of the project. This is applied in the strictest sense, that specific parcels in the project do not change.
3. The crediting period is 10 years and the liability period is an additional 10 years
4. It is assumed that most projects will be designed to implement NT as much as possible. RT will not triggering any reversal provides such a low coefficient that projects designed for this practice would not be feasible.

Table 3.6.2 Calculation of Credits within One Farm

Year	NT		RT		FT		Reversible SOC Additions		Proportion Of Land In		Proportional Reversal Coefficient	Reversal Credit	Total Reversible Pool	Net Annual Credits	Sum Of Credits
	ha	credits	ha	credits	ha	credits	NT	RT	NT	RT					
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**
1	1000	489	0	0	0	0	386	0	1.000	0.000	0.386	0	386	489	489
2	900	440	100	6	0	0	348	5	0.950	0.050	0.369	0	739	446	935
3	1000	489	0	0	0	0	386	0	0.967	0.033	0.375	0	1125	489	1423
4	800	391	200	13	0	0	309	10	0.925	0.075	0.361	0	1444	404	1827
5	500	244	300	19	200	-47	193	14	0.875	0.125	0.344	-69	1583	148	1975
6	1000	489	0	0	0	0	386	0	0.897	0.103	0.351	0	1969	489	2464
7	1000	489	0	0	0	0	386	0	0.912	0.088	0.357	0	2355	489	2952
8	1000	489	0	0	0	0	386	0	0.923	0.077	0.360	0	2742	489	3441
9	1000	489	0	0	0	0	386	0	0.932	0.068	0.363	0	3128	489	3929
10	1000	489	0	0	0	0	386	0	0.939	0.061	0.366	0	3515	489	4418
11	1000	0	0	0	0	0	0	0	0.939	0.061	0.366	0	3515	0	4418
12	1000	0	0	0	0	0	0	0	0.939	0.061	0.366	0	3515	0	4418
13	1000	0	0	0	0	0	0	0	0.939	0.061	0.366	0	3515	0	4418
14	1000	0	0	0	0	0	0	0	0.939	0.061	0.366	0	3515	0	4418
15	1000	0	0	0	0	0	0	0	0.939	0.061	0.366	0	3515	0	4418
16	0	0	0	0	1000	0	0	0	0.939	0.061	0.366	-366	3149	-366	4052
17	1000	0	0	0	0	0	0	0	0.939	0.061	0.366	0	3149	0	4052
18	1000	0	0	0	0	0	0	0	0.939	0.061	0.366	0	3149	0	4052
19	1000	0	0	0	0	0	0	0	0.939	0.061	0.366	0	3149	0	4052
20	1000	0	0	0	0	0	0	0	0.939	0.061	0.366	0	3149	0	4052

Following is a list of equations and detailed explanation of how values in this table are derived.

1. Calculation of Annual Credits based on Activity

This is a straightforward calculation, simply multiplying the area of land in each tillage activity by the appropriate coefficient. Therefore,

$C_{year\ x} = B_{year\ x} * Q$
$E_{year\ x} = D_{year\ x} * R$
$G_{year\ x} = F_{year\ x} * S$

2. Reversible Soil Organic Carbon Additions

This is the portion of the annual credit that is attributed to soil organic carbon removals, which is therefore at risk to loss or reversible. This must be accounted for separately.

$$H_{year\ x} = B_{year\ x} * T$$
$$I_{year\ x} = D_{year\ x} * U$$

3. Proportion of Land in No Till or Reduced Till

This is not the proportion of land in NT and RT for each year, but the proportion of land in NT and RT since project start. The values are recalculated each year to include the proportion from the most recent year in the calculation. Therefore,

$$J_{year\ x} = sum\ (B_{years\ 1\ to\ x}) / (sum\ (B_{years\ 1\ to\ x}) + sum\ (D_{years\ 1\ to\ x}))$$
$$K_{year\ x} = sum\ (D_{years\ 1\ to\ x}) / (sum\ (B_{years\ 1\ to\ x}) + sum\ (D_{years\ 1\ to\ x}))$$

It is important to note that J and K are not recalculated after the crediting period during the liability period, because no new credits are being issued during this latter period. Another way to justify this is to prevent the occurrence of a larger reversal coefficient for a producer who maintains a higher proportion of land in NT during most of the liability period. This producer may in fact be sequestering more net carbon that would actually help to counteract a reversal.

4. Proportional Reversal Coefficient

This value is recalculated on an annual basis, using the updated land area proportions in the previous step, and the reversal coefficients for soil organic carbon. Therefore,

$$L_{year\ x} = (J_{year\ x} * T) + (K_{year\ x} * U)$$

5. Reversal Credit

The reversal credit is calculated as follows:

$$M_{year\ x} = L_{year\ x} * F_{year\ x}$$

Reversal credits are only issued to projects utilizing permanent or offset credits, not temporary credits. If these reversals occur during the crediting period they can easily be paid back by reducing the amount of current or future offset credits to be issued. However, if they occur during the liability period there needs to be a real pay back by both the project proponent to the credit purchaser, and by the producer to the project proponent. This has further implications that will be discussed in the next section.

6. Total Reversible Pool

This is the annually calculated running total of the net reversible credits at risk to loss during the life of the project.

$$\mathbf{N}_{\text{year x}} = \mathbf{H}_{\text{year x}} + \mathbf{I}_{\text{year x}} + \mathbf{M}_{\text{year x}} + \mathbf{N}_{\text{year x-1}}$$

This pool increases from annual additions of SOC through NT and RT (ie. H and I) and decreases from annual reversals through FT (ie. M). While not evident in the table the reversible pool must never be allowed to go below zero. In other words it is possible, although not likely, that a farm may initially have a few years of NT but then revert to FT permanently. Once the reversible pool reaches zero no further reversal credits are generated, even if the FT activity continues in subsequent years.

7. Net Annual Credits

$$\mathbf{O}_{\text{year x}} = \mathbf{C}_{\text{year x}} + \mathbf{E}_{\text{year x}} + \mathbf{G}_{\text{year x}} + \mathbf{M}_{\text{year x}}$$

8. Sum of Credits

$$\mathbf{P}_{\text{year x}} = \mathbf{O}_{\text{year x}} + \mathbf{P}_{\text{year x-1}}$$

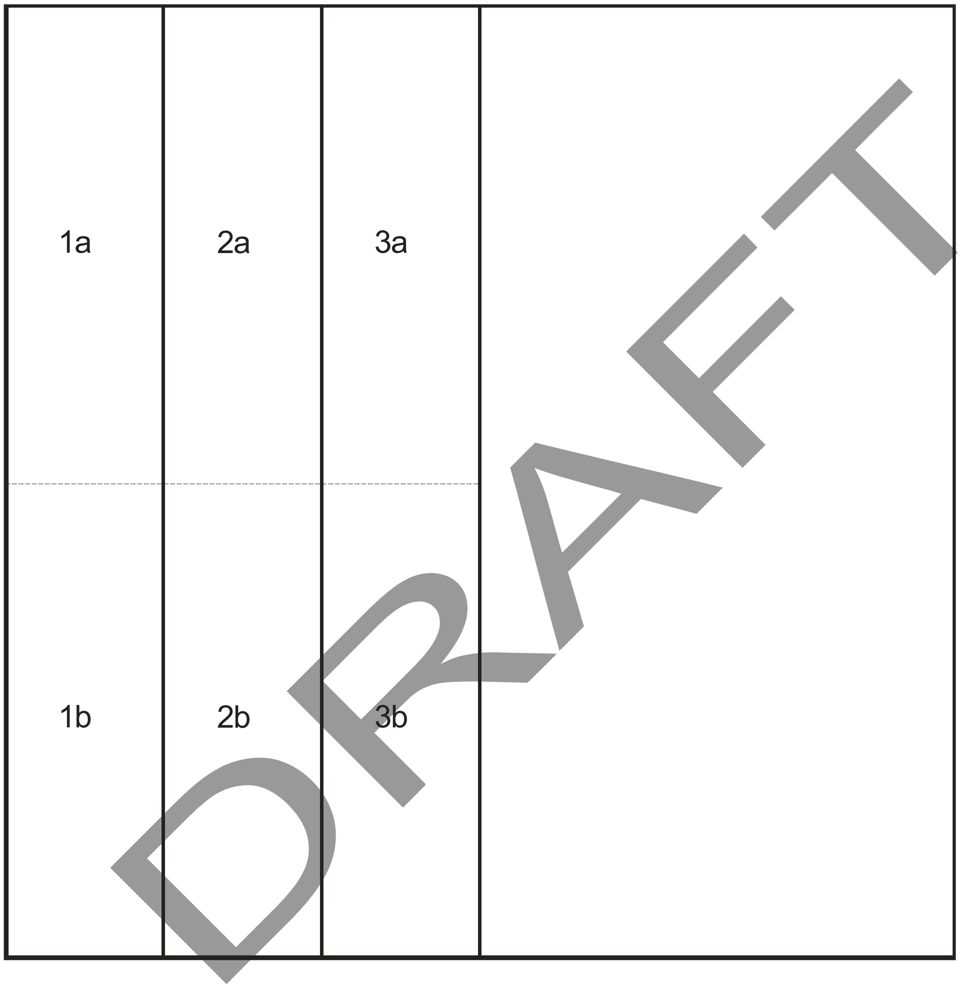
3.7 Impact of Changing Land Tenure on Implementation of Projects and Reversals

Due to the reality of flexible land tenure arrangements (ie. land sales, lease agreements) it is possible that the manager of a specific parcel of land may change several times during the life of a project (crediting and liability period). It is also possible that new land may enter a project part way through the crediting period.

Thirdly, it is conceivable that a new land manager may want to remove land from a project. This is easily done if this land has been issued temporary credits, since there is no liability period or reversal credits to be concerned with. However, if this land has been issued permanent offset credits, then the land must remain in the project until the liability period has passed. There could be a provision to buy out of the liability obligation by repaying the entire pool of reversible credits (ie. column N).

Based on the above it is recommended that the calculations presented in Table 3.6.2 be done at a more detailed level than an entire farm, that is at the legal land description and land parcel level. This may appear to add data management requirements, however, because data is already computer managed at the land parcel stage for annual field records, it is not difficult to extend the credit and reversal calculations at the same level. However, there is a further complexity relating to the fact that land parcel or field boundaries do not mesh with legal land description boundaries. This can best be explained and resolved through an example, as shown in Figure 3.6.2.

Figure 3.6.2 West Half-36-50-50-W5



In the previous example for John N. Till (see section 3 (a)) land parcel or field #2 was in the project.   If parcels #1 and #3 were also in the project then one form such as Table 3.6.2 could be used to track credits and reversals for all three parcels together, since they all belong to the same legal land description.

However, because this legal land description consists of two quarter sections (SW and NW) there is potential that the management of these parcels could be divided further at some point in the future. For example John N. Till could retain management of the NW quarter (ie. parcels 1a, 2a, and 3a), but the SW quarter (ie. 1b, 2b, and 3b) could be sold or leased to another manager. The normal mechanism for registering a legal interest or obligation (ie. requirement to maintain offset liability) is through a caveat or easement on the land title.

Therefore, in this example there is a requirement by the project proponent to maintain records at the quarter section level. The proponent may decide to do this at the outset even before such an event would occur, or decide to subdivide an existing parcel as a data management function only when it actually happens. The latter approach may seem reasonable, especially in light of the fact that land owners often have the ability to subdivide land parcels numerous ways that are smaller than conventional legal description (eg. even smaller than a quarter section).

However, it is important to note that data management functions associated with subdivision of parcels may be complex and potentially costly for the project proponent. If we consider the example from section 3 (a), it is obvious that field record sheets from all previous years would have to be reevaluated, because some tillage activities occurred in only certain parts of the land parcel and not equally in each quarter section. This reinforces the earlier comment to utilize GIS technology to make this analysis as efficient as possible. Also, it may be prudent to subdivide data at the outset from parcels that are already larger aggregates of smaller but common legal units. For example, sections and half sections (in the prairies) should be data managed as quarter sections.

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Annex I

Census of Agriculture Tillage System Calculation

Question #107
For the land seeded or to be seeded this spring, report the area of each of the following practices: include the area that was prepared last fall or this spring.
-Tillage incorporating most of the crop residue into the soil. TILLNO
-Tillage that retains most of the crop residue on the surface (include minimum tillage) TILLCONS
-NT seeding (include direct seeding into stubble or sod). TILLCONV

Question #109
If summerfallow land was reported in question 92, on page9, what is the area on which each of the following forms of weed control will be used in 2001
-chemical only CHEMSF
-tillage only TILLSF
-tillage and chemical combination on the same land COMBSF

Area of Land Reported (ha)

Year	Census Variable	Tillage System	Region: West	Dry Prairie	Parkland	East/Central	East
	TILLNO	NT	9,017	2,326,955	1,740,090	483,023	10,820
	TILCONS	RT	12,880	3,218,781	4,725,302	671,830	47,519
	TILCONV	FT	51,356	4,250,289	8,581,788	2,074,360	231,775
1996							
	CHEMSF	NT	1,353	385,294	166,848	3,981	876
	COMBSF	RT	5,734	1,298,681	958,877	9,228	565
	TILLSF	FT	9,928	2,246,647	1,102,984	13,078	1,607
2001	TILLNO	NT	16,041	4,215,621	3,734,951	759,075	17,356

TILCONS	RT	14,878	2,983,736	4,945,904	760,893	70,672
TILCONV	FT	66,373	3,186,109	6,283,599	2,137,310	281,897
CHEMSF	NT	614	624,641	194,859	2,486	531
COMBSF	RT	4,353	977,130	684,561	4,020	512
TILLSF	FT	8,358	1,365,338	764,949	11,070	1,733

Notes: The census also asks separate questions involving area of land in crop production and summerfallow. The area of total area of seeded land and summerfallow from these questions does not always equal the area of land generated from questions 107 and 109. However, to determine tillage adoption rates it is not necessary to know the absolute number of hectares, but rather the proportion of land in each system. Therefore, while not all land may be accounted for in questions 107 and 109, the proportion of land in each tillage system should accurately represent each region.

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and the federal government already developed a number of policy guidelines that were incorporated into the initial Offset System design. Some of these design elements, as described in the Offset System Technical Background Document (TBD), are listed below.

[192] To facilitate the participation of agriculture sink projects in the Offset System, the Government of Canada, in collaboration with provinces/territories, is developing a quantification protocol for soil sinks. Proponents will have the option to choose between using the default quantification protocol, or could develop a customized methodology as described in the next section.

[193] The quantification protocol will use removal factors to quantify carbon stock changes. Project Proponents that choose to use the protocol will multiply the verified number of hectares over which the practice has been implemented by the removal factor in the protocol. If there is a change in practice that could result in the release of carbon removed, the Proponent will calculate the reversal using a reversal factor set out in the protocol.

[194] The default approach will be designed to achieve accuracy at the aggregate level. Removal factors will require adjustment on an on-going basis to ensure the accuracy of the factors are maintained. For example, an adjustment will be required if additional Project Proponents join the group using the default approach or if Project Proponents leave the group to use a customized approach. Adjustments to the removal factors will not affect the credits already issued.

[195] The default approach will not require Project Proponents to provide historical information on practices implemented on the project area. However, the removal factors must account for the fact that removals achieved by projects implemented before the Project Eligibility Start Date (01 January 2000) are ineligible to receive credits.

Much of this guidance was developed by the Working Group on Offsets (WGO), which preceded the Offset System Program Authority. The WGO has provided minimal background material and rationale for this guidance. Within this context and policy framework t