

ASSESSMENT OF DIFFERENT QUANTIFICATION APPROACHES AND APPLICATION OF MULTIPLE PRACTICES FOR A SINGLE FARM UNIT

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INTRODUCTION

Soil and crop management systems are inherently complex, and therefore it is not surprising that greenhouse gas impacts from these systems are also complex. Furthermore, scientists have developed different approaches to quantifying GHG impacts, which range from direct measurement to model estimations.

The impact of this complexity is that there are many issues and possible options for designing quantification methodologies for carbon offset projects. It is becoming clear that it is much more efficient to develop standardized protocols which can be used by all project proponents, rather than having project proponents individually grapple with these issues and options. While a standardized protocol may require periodic review and updating, once it is in place it can be easily implemented with minimal project development costs.

Currently, there are a number of protocol development processes in Canada, each linked to different existing or potential carbon offset systems. While this creates challenges, there is some attempt to coordinate protocol development, through various means. Some of these are formal arrangements, for example through groups like Climate Change Central in Alberta, while many others are informal discussions between scientists, industry / stakeholder representatives, and GHG offset design experts.

This paper addresses a number of challenging issues relating specifically to development of protocols for GHG carbon offsets achieved through soil and crop management. The issues include the following:

- Applicability of different methods for quantifying soil carbon sequestration
- Approaches for quantifying N₂O impacts related to improved soil nutrient management
- Ability to stack multiple protocols involving multiple practices at the single farm level

MATERIALS AND METHODS

Protocol development for soil and crop management practices has only been occurring in Canada since 2006. There are very few if any formally published documents that assess the 3 types of issues identified above. The concepts and suggestions presented here originate primarily from draft documents and ideas developed through recent protocol development processes in Canada that the author has been involved with.

RESULTS AND DISCUSSION

1. Applicability of different methods for quantifying soil carbon sequestration for offset projects

Quantifying soil carbon sequestration is challenging for a number of reasons, including the following:

- Sequestration rates due to practice change are low, although significant over a long period
- Soil properties are highly variable, even at the local field scale, resulting in high spatial variability in carbon sequestration
- Changes in total soil carbon must account for both a change in carbon concentration and soil bulk density.

Traditionally, real soil carbon change can only be accurately measured by analyzing soil carbon concentration and soil bulk density from soil samples taken just before and sometime after a practice change at a specific point location. There has been some progress to develop less expensive methodologies to assess soil carbon concentration, including remote sensing, but assessing bulk density remains an expensive task. The issue then becomes the relatively large number of samples required to detect significant soil carbon change over an area of land, given high spatial variability and low sequestration rates.

As a result scientists have developed soil carbon models which attempt to extrapolate results from point sources to larger areas of land. The most common model in use in Canada is Century. Its primary application for a number of years has been for estimating soil carbon change on agricultural land as part of its GHG inventory reporting under the United Nations Framework Convention on Climate Change. (McConkey, 2006). The primary practices quantified for this purpose are a change in tillage system, reduction in summerfallow, and conversion of annual cropland to perennial vegetation. For this application the model generates coefficients for each of these practice changes for each of five regions encompassing the entire agricultural land base in Canada.

Since 2006, these or similar coefficients have been used for developing GHG offset protocols and projects for tillage system change in Canada. It is recognized that this model output at a large regional scale doesn't accurately represent real carbon change at the farm or even local area scale. This is not a concern for projects that involve a large pool of land widely distributed over a large scale region, since the coefficient is designed to reflect this scenario. Nevertheless, individual farmers or those located within a smaller region may feel that they are able to sequester greater carbon than what is provided through the model output at a large regional scale.

Therefore, a number of groups have explored various other options for quantifying soil carbon change in GHG offset projects. A Soil Management Technical Working Group (SMTWG) working on protocols in 2006 initially considered on farm point measurements to quantify carbon change on an individual farm, but concluded that the high cost associated with taking enough soil samples would negate any benefit resulting from relatively low soil carbon increases (Paragon, 2006). The SMTWG recognized that this approach could be improved by taking soil samples over a larger area to represent soil carbon change for a block of farms with similar

management. This would result in somewhat fewer samples required per farm, but would likely still deem this approach too costly.

Another option involves scaling down models to operate at a smaller regional scale. While there is a need for additional point measurements to validate the model, the number of measurements would be substantially less than an approach that uses measurements in the absence of a model. Some groups have even used models that operate at multiple scales for different components. For example, one U.S. based system called C-Lock provides model generated coefficients based on generalized regional historical baseline practices, and farmer specific information for new practice changes (Zimmerman et al, 2005). This raises additional questions on the validity of using mixed quantification approaches within the same protocol or project.

No quantification approaches, other than the large scale regional approach, have been developed in a protocol or implemented in a project in Canada. Nevertheless, the Alberta Specified Gas Emitters Regulation provides a guidance document for developing model based custom coefficients involving soil carbon sequestration (Alberta Environment, 2007). This guidance requires adherence to a number of key criteria including the following:

- supported through peer reviewed literature
- assessed by independent, qualified 3rd party
- validated against relevant long term site data
- inclusion of a sensitivity and uncertainty analysis
- generation of custom coefficients based on proper model initialization and multiple runs

2. Approaches for quantifying N₂O impacts related to improved soil nutrient management

After soil carbon sequestration, improved soil nutrient management has been identified as the next most important mechanism by which GHG benefits and potential carbon offsets result from beneficial soil management practices.

The foundational principles for effective nutrient management include applying the best source or form, at the correct rate, at the right time, and in the right place to enable optimal utilization by crops. The resulting assumption is that nutrient losses to the environment, such as leaching, runoff, and gaseous losses (including nitrous oxide) are minimized with effective nutrient management.

There are a host of specific practices that potentially reduce nitrous oxide emissions through improved nutrient management. However, it is often difficult to quantify these impacts in measurement based research, because of the large spatial and temporal variability of N₂O emissions associated with inherent soil/landscape variation and weather fluctuations. As a result it is also difficult to develop model based coefficients for specific practices.

The International Panel on Climate Change (IPCC) approach to quantify N₂O emissions in agricultural soil is to base it largely on the rate of nitrogen fertilizer application. Agriculture and Agri-Food Canada has developed an IPCC Tier II type approach in its GHG inventory reporting process that also includes the effect of spring thaw, landscape position, summerfallow, irrigation

and tillage system on N₂O emissions (Rochette, 2005).

Therefore the national GHG inventory process does not include assessment of other specific nutrient management related practices such as

- Improved timing of fertilizer and manure application, including elimination of fall application and split application of nutrients during the growing season to better match crop needs with growing conditions
- Improved soil test and analysis methods to determine optimal N application rates
- Improved slow release forms of nitrogen fertilizer, such as Agrium's ESN
- Increased incidence of legume and pulse in crop rotations to reduce nitrogen fertilizer application
- Variable rate nutrient application
- GPS controlled tracking to eliminate overlap of nutrient application
- In field winter grazing or feeding of cattle instead of confined feeding
- Green manures and cover crops

Since 2006 a number of initiatives have begun considering ways to quantify GHG impacts of practices such as these, as potential use for carbon offsets. It is obvious that there are significant challenges in quantifying all potential sources and sinks, such as soil carbon, N₂O, and energy use.

Nonetheless, it has become evident that for N₂O a simplified approach is to consider only the impact of the practice on the amount of nitrogen applied. For example, one can use the IPCC Tier II method developed for the Canadian GHG inventory to apply an N₂O coefficient based solely on the reduction in nitrogen fertilizer applied. There are a number of advantages of this approach:

- it is not necessary to understand the complex science by which specific practices help to reduce N₂O
- it is much easier to monitor and verify changes in the rate of N application, than changes in other specific practices

The disadvantage of this approach is that it assumes that the proportion of N applied that is lost via N₂O remains fairly constant for varying N management practices that impact rate within one region. In reality, one specific practice may have a greater impact on N₂O than another, relative to impact on N rate, and this is not accounted for. Nevertheless, this simplified approach may be acceptable if it can be demonstrated to also be conservative in estimating N₂O reductions.

Another concern is that implementing a practice that reduces N₂O does not necessarily result in a reduction in N application. For example, the reduction may result in increased N utilization by crops and increased yield. Nevertheless, it is assumed that most farmers are currently applying N at rates that maximize economic yield. In that case most practices that reduce N₂O should also reduce N application rate.

This approach has already been used in developing a draft protocol for nitrogen fertilizer reduction in corn production in Ontario (Haak and SMTWG, 2006). The Alberta government is currently beginning work on a "Nitrous Oxide Emission Reduction" protocol which is

considering various issues and approaches relating to nutrient management practices.

3. Ability to stack multiple protocols involving multiple practices at the single farm level

The previous sections have demonstrated that GHG emission reductions can potentially be achieved through multiple practices on a single farm. Farmers are interested in maximizing their carbon offsets by including as many beneficial practices as possible in a GHG reduction project. While the benefit of any single practice may be quite small, it may be feasible to add a practice to a project since the incremental cost may be minimal. For example, much of the information being collected for monitoring and verification of already existing practices may also be sufficient for the added practice.

The past approach for most protocol development has been to focus on high priority practices that have the greatest potential to generate carbon offsets, (eg. no till). However, there is interest in developing additional protocols for additional practices. These include practices related to nutrient management, as listed in section 2, as well as other soil carbon sequestering practices such as summerfallow reduction, and increasing the frequency of perennial forages in rotation with annual crops.

It is anticipated that a number of protocols involving multiple practices could be integrated in a single project. In order for this to work, it must be clearly demonstrated in the protocols that GHG emission reductions from each are unique and additive, that is, there is no double counting. There are a number of issues that must be addressed in order to demonstrate uniqueness. Two important ones are practice interactions and mixing quantification approaches.

a) Practice Interactions

There are numerous practice interactions, and some discussion around two practices, namely no till and land application of nutrients, will provide an example of how to address and resolve this type of issue.

Existing no till protocols are based primarily on soil disturbance, and therefore already consider the amount of soil disturbance that occurs during nutrient application. (Haak and SMTWG, 2006). For example, the no till activity definition allows for surface application of nutrients with no incorporation as well as low disturbance placement or injection of nutrients separate from or part of the seeding operation. On the other hand, high soil disturbance placement or incorporation of nutrients does not meet the no till definition. Another important aspect of nutrient application is timing. The no till definition allows for nutrient application at any period of time, including during the fall season prior to spring seeding, because timing has nothing to do with soil disturbance.

Therefore, if one wants to pursue a nutrient land application protocol that can be stacked with the no till protocol it will be able to consider all impacts related to timing. It may also be able to consider the impact of switching from surface application with no incorporation to low soil disturbance placement or injection, because these both fit the definition of no till and are therefore not differentiated in that protocol. However, this protocol would not be able to

consider a switch in practice from high to low soil disturbance nutrient application without a change in timing, because this change is already accounted for in the tillage system switch from full till to no till.

b) Mixing Quantification Approaches

Mixing quantification approaches for different protocols that are implemented on the same farm can be easily rationalized for practices that are unrelated with minimal interactions. For example, a farm could implement a no till project using a regional approach for baseline and coefficients, while at the same time have a biodigester project using an individual approach for baseline and project performance.

However, mixing of approaches may be more difficult for practices that are more closely related. For example, there may be interest in developing a summerfallow reduction protocol using an individual producer baseline, while at the same time utilizing the no till protocol which employs a regional baseline discount. The rationale for a regional baseline in the no till protocol is partly based on the difficulty in verifying historical tillage practices on individual land parcels. However, verification of fallow at the scale of individual land parcels is quite easy through methods such as remote sensing analysis and crop insurance records.

Different baseline approaches for related practices may be acceptable but must be fully rationalized by addressing and resolving all interaction issues. This may require going back to the existing no till protocol to provide additional rationalization for how that protocol relates to a fallow reduction protocol. Specific details for this example are too complex to fully address within the scope of this paper.

A potential approach to addressing many of the issues discussed in this paper involve the use of integrated GHG models that work at the individual farm level. A number of these models exist including the Comet-VR (USDA, 2007) and Holos (NLWIS, 2008). However, it is possible that these models do not provide the level of rigour required for GHG carbon offset projects, as suggested by various guidance documents provided by ISO 14064. (ISO, 2006) and the Alberta Specified Gas Emitters Regulation (Alberta Environment, 2007). Nevertheless, it is anticipated that further development of models is a key method to quantify GHG impacts of multiple practices for the purposes of generating carbon offsets in the future.

REFERENCES

Alberta Environment, 2007, Soil Carbon Custom Coefficient/Protocols Guidance Document: Specified Gas Emitters Regulation, 13 pages, Website:
<http://www.carbonoffsetsolutions.ca/offsetprotocols/finalAB.html>

Haak D and Soil Management Technical Working Group (SMTWG) for Canada's GHG Offset System., 2006, Tillage System Default Coefficient Protocol: based on Canada's Offset System for Greenhouse Gases Technical Background Document 2005, 77 pages, Note: Draft document not formally published, but available from author)

- Haak D and Soil Management Technical Working Group (SMTWG) for Canada's GHG Offset System., 2006, Nitrogen Fertilizer Reduction in Corn Production Protocol: based on Canada's Offset System for Greenhouse Gases Technical Background Document 2005, 78 pages, Note: Draft document not formally published, but available from author)
- Haak D, 2007, Soil Management Protocols and Projects for Greenhouse Gas Offsets in Canada, 18 pages, Agriculture and Agri-Food Canada Website: <http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1191435366810&lang=e>
- International Standards Organization (ISO) 2006, ISO 14064-2 Specification with Guidance at the Project Level for Quantification, Monitoring, and Reporting of Greenhouse Gas Emission Reductions or Removal Enhancements, Standards Council of Canada, CAN/CSA-ISO 14064-2:06
- McConkey B, 2006, Carbon Change Estimation Method Used for Agricultural Practice Changes in Canadian Greenhouse-Gas Inventory, 9 pages, Unpublished Draft Document prepared for National Carbon and Greenhouse Gas Accounting and Verification System (NCGAVS)
- National Land and Water Information Service (NLWIS), 2008, Holos: A tool to estimate and reduce GHGs from farms, Website: http://www.agr.gc.ca/nlwis-site/print_e.cfm?s1=tools_outils&page=intro
- Paragon Soil and Environmental Consulting Inc., 2006, Guide to Development of Customized Agricultural Soil Carbon Sink Protocol for Greenhouse Gas Emission Reductions and/or Removals under Canada's Offset System (DRAFT), 80 pages, Unpublished draft prepared for Soil Management Technical Working Group
- Rochette P. Worth D., 2005, Inventory of N₂O Emission from Canadian Agricultural Soils at the EcoDistrict Scale Using an IPCC Tier II Methodology, 54 pages, Unpublished Draft Document prepared for National Carbon and Greenhouse Gas Accounting and Verification System (NCGAVS)
- Soil Resource Group, 2006, Exploration of development of soil management protocol opportunities for greenhouse gas emission reductions and/or removals under Canada's Offset System, 40 pages, Unpublished draft prepared for Soil Management Technical Working Group
- USDA, 2007, Voluntary Reporting Carbon Management Evaluation Tool (COMET-VR), Website: <http://www.cometvr.colostate.edu/about/>
- Zimmerman P. Price M. Peng C. Capehart W. Updegraff K. Kozak P. Vierling L. Baker E. Kopp F. Duke G. Das C., 2005, C-Lock (Patent Pending): A System for Estimating and Certifying Carbon Emission Reduction Credits for the Sequestration of Soil Carbon on Agricultural Land, Mitigation and Adaptation Strategies for Global Change, Volume 10, Number 2, April 2005 , pp. 307-331(25), Springer