Feasibility Study for a Measurement Model of Best Management Practices (BMPs) Impacts on Greenhouse Gas (GHG) Emissions and Water Quality
Final Report

Prepared For

Alberta Agriculture and Forestry

Prepared By

Serecon Inc.
and
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Dear Ms. Sieniewicz:

RE: FEASIBILITY STUDY FOR A MEASUREMENT MODEL OF BEST MANAGEMENT PRACTICES (BMPS) IMPACTS ON GREENHOUSE GAS (GHG) EMISSIONS AND WATER QUALITY
FINAL REPORT

We are pleased to provide you with this Final Report on the Feasibility Study for a Measurement Model of Best Management Practice (BMP) Impacts on Greenhouse Gas Emissions and Water Quality.

This Final Report presents the Project Team's findings for all five phases of the project. Data has been compiled in matrix format, and is contained in Excel spreadsheets submitted along with this written report. The spreadsheet "BMP impact study Annex 1 Ph1-2 150416" contains Phase 1 and 2 data. The spreadsheet "BMP impact study Annex 2 Ph3-5 and factsheets 150416" contains the data for Phases 3, 4 and 5, as well as summary fact sheets on the reviewed tools. These spreadsheets comprise the actual data generated throughout the project. The written report explains the rationale and structure of each of the spreadsheets, presents our findings, and summarizes our recommendations and conclusions.

We appreciate the opportunity to work with you on this most interesting project. Please do not hesitate to contact me if you have any questions.

Yours truly,
SERECON INC.

Robert E. Burden, MBA, AVA, P.Ag.
Edmonton Office

Enclosure

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Table of Contents

List of Tables and Figures

Background

Considerable progress has been made in recent years, in Canada and worldwide, in quantification of the environmental impacts of activities on the farm. The challenge is to identify the best management practices (BMPs) with the highest cost-effectiveness in terms of greenhouse gas (GHG) and water quality impacts, and focus on measurement that is sensitive to changes that are practical from the farmer's perspective.

The Growing Forward 2 On-Farm Stewardship Program provides financial support to Alberta farmers implementing projects and management practices that have positive impacts on water quality, while also improving management of inorganic agricultural wastes.

On-Farm Stewardship funding is presently available for projects/practices in the following five categories:

- Grazing management
- Manure management
- Pesticide management
- Agricultural waste management
- Innovative stewardship solutions

Looking to the future, the On-Farm Stewardship Program is considering factors beyond the impacts of BMP implementation on water quality and inorganic waste management. Consideration in future programming may also be given to:

- BMP impacts on greenhouse gas emissions
- Demand from sustainability markets for BMPs

Thus, it is anticipated that the scope of the On-Farm Stewardship Program may expand. For this reason, the Farm Stewardship Centre has submitted a proposal to Growing Forward Business Development Initiatives to study the feasibility of developing a model (or a combination or existing models) to measure BMP impacts. The ultimate purpose of this model is to optimize the access of Alberta farmers to environmental sustainability markets.

This gives rise to the terms of reference for the present project. This project is to assess the feasibility of developing a model(s) that will measure the impacts of implemented BMPs on both water quality and GHG emissions, for BMPs that are in demand from sustainability markets.

Objectives

This project is to assess the feasibility of developing a model (or models) to measure the environmental impacts of BMPs.

The ultimate objective for this model is to facilitate access for Alberta producers to markets for environmentally sustainable products. One of the critical success factors is the need to ensure that this model is a farmer-friendly calculator that will quantify and document the environmental impacts of BMP implementation. These impacts are to be quantified as accurately as possible without the need for actual physical measurements on the farm. The BMP impacts of interest are those within the following specific areas of sustainability:

- GHG emissions: direct and indirect greenhouse gas emissions resulting from farm operations (e.g. fuel for machinery, fertilizer application, etc.), land use changes, and in some cases, along the supply chain (e.g. feed production, transport). Carbon sequestration in crops is accounted in this indicator.
- Water quality: presence of nutrients, salts, metals and pathogens in surface water and groundwater

Overall Approach

Overview of Analytical Approach

Identification of Critical Success Factors for Modelling BMPs

Using its experience with modelling of BMP impacts, the Project Team identified critical success factors for an effective BMP impact model. Key success factors for BMP impact models include

- Objectivity
- Basis in sound science
- Easy access to necessary data for producers

These success factors served as a marking key in the assessment of existing models, and of the present potential to model the BMPs that are of high priority to the On-Farm Stewardship Program.

Development of Analytical Process

With these key factors in mind, the Project Team developed processes to achieve the following specific objectives:

1. Prioritize BMPs on the basis of
   - Environmental impact – GHG emissions and water quality
   - Demand from sustainability markets
2. Assess the feasibility of modelling these priority BMPs

Development of Key Deliverables

These processes enabled the development of our deliverable – the development of a database that provides the ability to

1. Identify the most important BMPs for the On-Farm Stewardship Program to support
2. Identify the existing capacity to model these priority BMPs, and identify the gaps in modelling capacity

Process Overview

The analysis undertaken for this project falls into two parts:

1. First-level analysis – prioritization of BMPs
2. Second-level analysis – assessment of models and data sources

Part 1 – Prioritization of BMPs

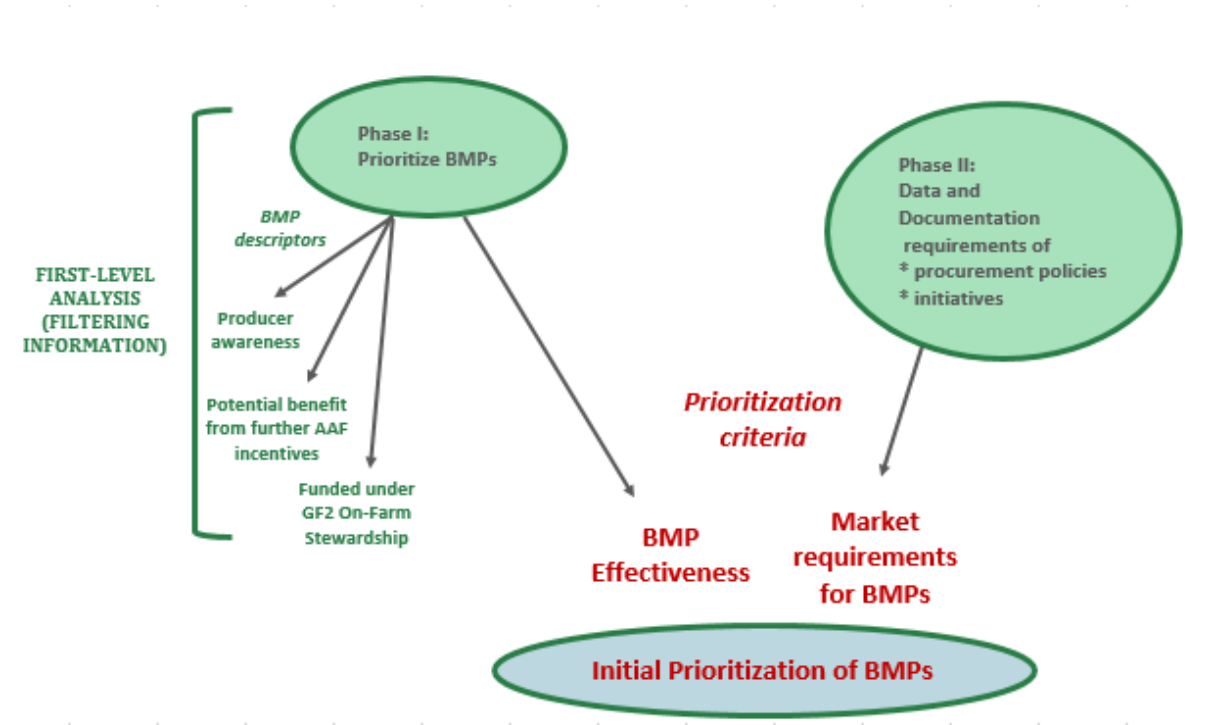
The first-level analysis undertaken for this project addressed the question: "Which BMPs do we most need to model?"

Phases 1 and 2 of the project provided the basis for prioritizing BMPs

- Phase 1 compiled information that characterizes relevant BMPs, including their environmental impacts
- Phase 2 compiled information that documents the demand for each BMP from sustainability markets

To prioritize the BMPs of interest, a combination of information from Phases 1 and 2 was used (see Figure 1).

Figure 1: Prioritization of BMPs – Phases 1 and 2



Part 2 – Assessment of Models and Data Sources

The second level of analysis undertaken went into greater depth, and addressed the question: "What is the existing capacity to model the impacts of the priority BMPs?"

This question was addressed in Phases 3 and 4 of the project

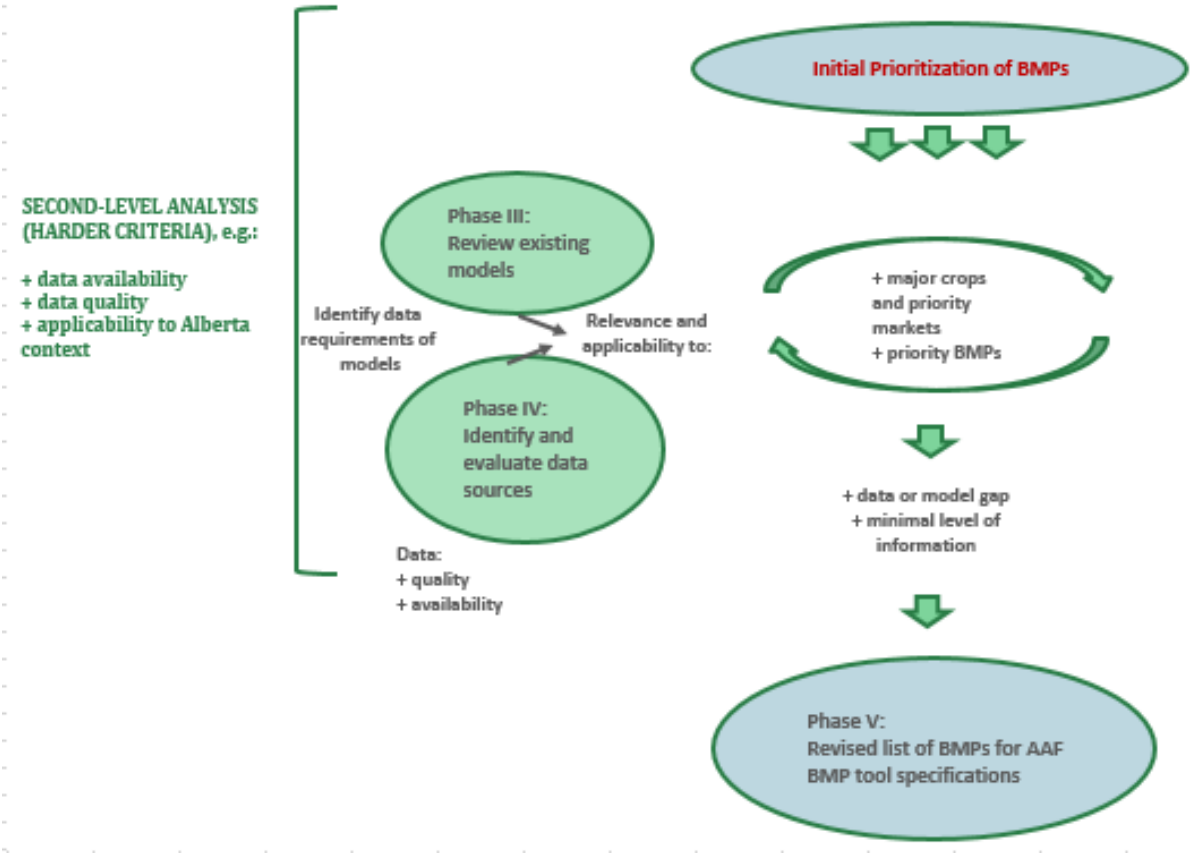
- Phase 3 compiled data to provide for assessment of existing models, including their data requirements
- Phase 4 compiled information on data sources

Phases 3 and 4 focused on assessing the relevance and applicability of existing models, and existing data sources, to

- Priority BMPs, as identified in Phases 1 and 2
- Alberta's major crops

Phases 3 and 4 thus generated the information base necessary to identify gaps in existing modelling capacity and data sources, from the standpoint of modelling the impacts of the priority BMPs identified in Phases 1 and 2 (see Figure 2).

Figure 2: BMP Impact Model Feasibility Study – Phases 3, 4 and 5



Analytical Process and Findings

Phase 1 – Identification of BMPs

Phase 1 Objectives

The objective of Phase 1 was to develop the information basis for a prioritized list of BMPs that should be considered for inclusion in an eventual Alberta BMP impact model. Focus was placed on BMPs with impacts on greenhouse gas (GHG) emissions and water quality. As well, priority BMPs had to be relevant in Alberta.

Later in the project, the BMPs identified in Phase 1 were linked to the information requirements of sustainability markets, as identified in Phase 2. This implemented an additional filter on the list of BMPs from Phase 1, by highlighting those with impacts of most interest to sustainability markets.

Phase 1 Process

Phase 1 consisted of capturing information that defines the importance of each BMP to a future BMP impact model. This required a process that enabled the Project Team to identify the importance of each BMP on the basis of a set of relevant criteria.

The following process was followed to identify and prioritise BMPs for completion of Phase 1:

1. **Listing of BMPs given priority by the Growing Forward 2 Stewardship Programs**. The Alberta Agriculture and Forestry (AAF) Project Management Team provided information on the BMPs funded under the GF2 On-Farm Stewardship Program. From this information, the Project Team developed an initial list of BMPs for prioritisation.
2. **Definition of descriptive information**. The Project Team defined relevant information on which to rate the suitability of each BMP for consideration in a future BMP impact measurement tool. AAF provided input on these information categories, and this input was incorporated. The final Phase 1 documentation of BMPs included (column references are to spreadsheet "BMP impact study Annex 1 Ph1-2 150416", tab "BMP list"):
    a) Prevalence (and encouragement) of the BMP in Alberta (ESA Tracking Survey)(column H)
    b) Cost-effectiveness of implementation of the BMP (column F)
    c) Producer recognition of the BMP (ESA Tracking Survey)(column G)
    d) Potential benefit from further incentives to implement the BMP (ESA Tracking Survey)(column I)
    e) Funding status of each BMP under the On-Farm Stewardship Program (columns N and O)
    f) Impact of the BMP on GHG emissions (columns , K and M)
    g) Impact of the BMP on water quality (columns L and M)

This information was summarized in a matrix, in the form of an Excel spreadsheet, with a row for each BMP and a column for each of the above information categories. Spreadsheet "BMP impact study Annex 1 Ph1-2 150416", tab "BMP list" summarizes 33 BMPs in this way.

3. **Identification of prioritization criteria.** From the information categories defined above, the Project Team identified prioritization criteria in consultation with the AAF Project Management Team. It was decided to prioritize the 33 BMPs on the basis of the following three criteria, equally weighted:
   - Impact of the BMP on GHG emissions
   - Impact of the GHG on water quality
   - Demand for the BMP from sustainability markets (information from Phase 2)

4. **Prioritization of BMPs on the basis of environmental impacts.** Methodologies were required to rate the impact of each BMP on GHG emissions and water quality. Input was sought from AAF experts on BMP impacts on these sustainability areas.

   Readily applicable data on these BMP impacts does not exist, for several reasons. For example, BMP impacts are heavily dependent on a variety of site characteristics, which vary widely throughout Alberta. Varying initial conditions and timing also affect BMP impacts. In the case of water quality impacts, Alberta researchers have found it necessary to test combinations of BMPs rather than individual BMPs, in order to achieve the impacts desired. As a result, scientific evidence of the water quality impacts of individual BMPs does not necessarily exist.

   For these reasons, an expert opinion approach to rating BMP impacts on GHG emissions and water quality was adopted. Given these issues, it was decided that the subjective opinion of individuals immersed in the relevant research, with a strong sense of how the various BMPs perform in the field, represented the best possible approach. In the absence of research specific to the information needs of the Feasibility Study, this approach enabled the Project Team to tap into some of the best knowledge available.

5. **Rating of BMP environmental impacts.** Mr. Tom Goddard, Senior Policy Advisor with AAF (GHG emissions), and Dr. Barry Olson, Soil and Water Research Scientist with AAF (water quality), provided subjective ratings of the environmental impacts of the 33 BMPs. The keys and spreadsheet references to these ratings are presented in Table 1.

Table 1: Structure of Ratings of BMP Impacts
(spreadsheet references are to "BMP impact study Annex 1 Ph1-2 150416", tab "BMP list")

	Expert Input From:	BMP Impact Rating Based On:	Magnitude Rating	Scale Rating	Overall Rating	Normalized Rating
GHG Impact	Mr. Tom Goddard	magnitude x scale	**-1** (will increase GHG emissions) **to 3** (strong ability to reduce GHG emissions)	**1** (local scale, e.g. farmyard only) **to 3** (large scale, i.e. applied to most of the farm area)	-3 to 9	**-1** weak increase to GHG emissions **0** negligible impact **1** weak GHG reduction **2** moderate GHG reduction **3** strong GHG reduction
GHG Impact Spreadsheet Reference			Column J	Column K	Column X	Column Y
Water Quality	Dr. Barry Olson	magnitude	**0** (negligible impact) **to 3** (strong ability to improve water quality)		0 to 3	**0** negligible impact **1** weak ability to improve WQ **2** moderate ability to improve WQ **3** strong ability to improve WQ
Water Quality Spreadsheet Reference			Column L		Column L	Column L

Phase 1 Findings

The Phase 1 preliminary results are presented in matrix form (Excel spreadsheet "BMP impact study Annex 1 Ph1-2 150416", tab "BMP list"). This matrix presents the following parameters:

- 14 columns (columns A to N), the first three identifying and describing the BMPs, and the next 11 presenting information on the status of each BMP in Alberta, and on its environmental impacts. Conditional formatting is used to provide a visual assessment of each BMP's impacts on GHG emissions and water quality. Note that this information on environmental impacts, together with information on market demand from Phase 2, provides the basis for prioritization of the BMPs for further analysis in Phases 3 and 4.
- 33 rows, each representing an individual BMP

Key Findings from the Phase 1 analysis of BMPs may be summarized as follows:

- 33 BMPs, covering 7 BMP areas, were analyzed in Phase 1
- 13 of these are presently funded under the On-Farm Stewardship Program
- 5 (15%) of the BMPs have moderate or strong impact on GHG emissions
- 24 (73%) of the BMPs have moderate or strong impact on water quality

Information Sources

Information sources engaged include:

- Alberta Environmental Farm Plan
- AAF input on the importance of respective BMPs
- 2014 Environmentally Sustainable Agriculture Tracking Survey Report (AAF)
- Alberta Agricultural Operation Practices Act (AOPA)
- Nutrient Beneficial Management Practices Evaluation Project (AAF)
- Watershed Evaluation of Beneficial Management Practices (WEBs) (AAFC)
- Fertilizer Use Survey initiated in 2014-15 under the Canadian Field Print Initiative
- Contacts identified by AAF

Phase 2 – Identification of Data and Documentation Requirements

Phase 2 Objectives

The objective of Phase 2 was to identify and list the measurement and documentation requirements of sustainability markets, so as to enable characterization of each market as to its requirements for each BMP.

Phase 2 Process

In addition to the broad range of programs and initiatives identified in the proposal, this review included sustainability assessment guidelines and certifications, which are strong sources of inspiration for the development of requirements for the various markets.

This phase included three main steps:

1) Identification and listing of procurement policies and sustainability initiatives
2) Search of market criteria, and identification of common and specific requirements of identified sustainability markets
3) Compilation of data and documentation requirements, by market/initiative, in matrix form (See spreadsheet: "BMP impact study Annex 1 Ph1-2 150416", sheet "Documentation of market"):

Each program or initiative was documented according to the following sets of information :

- General description of the program or initiative (columns B to K):
  - Title/name
  - Brief description
  - Type of program or initiative (Regulation, Protocol or methodology, Standard or certification, Policy or framework, Assessment tool, checklist compliance, funding program, support program, sustainability guidelines or criteria)
- Measurement and documentation needs (requirements) for each program or initiative (description of the requirements) – columns L to Q
  - Documents
  - Calculators/tools
  - Protocols, methodologies
  - Standards or certifications
  - Specific data and quantitative or qualitative information
  - Verification
- Source or reference (website or online documentation) – column R
- Relevance to BMPs (list of BMPs identified in Phase 1)
  - Each reference or mention of specific BMPs in each program or initiative was flagged with an "x" symbol in columns S to AZ.

In total, 68 initiatives were assessed in Phase 2 of the project. These fell into two groups:

1) Initiatives with strong influence on market requirements for BMPs, including
   - Funding or support programs
   - Sustainability guidelines or criteria (from agri-food associations or companies)
   - Regulations
   - Policies or frameworks
2) Initiatives with less direct impact on market requirements for BMPs, including
   - Protocols
   - Certification schemes
   - Standards

Note that a rating of the influence of the set of initiatives with strong influence on market demand for BMPs, only, was used to prioritize BMPs, along with ratings of environmental impact of BMPs from Phase 1.

Spreadsheet "BMP impact study Annex 1 Ph1-2 150416", sheet "Market demand" summarizes market demand for each BMP, based on occurrence of / interest in the BMP identified for each initiative. Conditional formatting is used on this sheet to identify strong (red) through weak (green) market demand for each BMP. As well, this score for market demand for each BMP is reproduced on spreadsheet "BMP impact study Annex 1 Ph1-2 150416", tab "BMP list" (columns P, Q and R), where it feeds into the prioritization of BMPs, along with the scores for the environmental impacts (GHG emissions and water quality) of each BMP.

Phase 2 Findings

BMP Areas of Interest to Markets

Certain common themes and BMP areas emerged from the Phase 2 analysis as being of interest to sustainability markets. Greenhouse gas (GHG) emissions are covered directly or indirectly in the majority of programs and initiatives identified (over 40 out of 68). Ranging from specific protocols for the reduction of GHG emissions through low residual feed intake in beef cattle to more general Environmental Product Declarations (EPDs), programs and initiatives have all identified practices aiming to reduce GHG emissions, or provided guidelines to quantify them. BMP categories that are closely related to GHG emissions are livestock yards, soil management, nutrient management, manure use and management, and pest management. While energy efficiency or feed-related practices can help reduce GHG emissions, no BMPs related to this type of practice were identified in Phase 1. However, energy efficiency programs and feed-related protocols are listed in the matrix for documentation purposes.

Among the listed BMPs, the ones related to manure use and management, soil management, nutrient management, pest management and water bodies have most coverage in the programs and initiatives identified.

Market demand was relatively strong for BMPs in the following areas:

- Nutrient management and manure use and management - with respect to impacts on GHG emissions
- Soil management – reduced tillage practices, crop rotation, incorporating perennial or pulse crops
- Pest management – pesticide drift minimization, rinsate disposal
- Water bodies – restoration of wetlands, buffer zones

A good correlation seems to exist between market interests and the availability of protocols/methodologies, certifications and standards. This means that the market is generally interested in BMPs, which could be defined or framed by existing normative tools. On the other hand, there are several relevant standards/protocols for the "Trees, Shelterbelts, Woodlots and Bush" set of BMPs, but less market interest in these topics.

Our review of the market also involved the determination of the "type" of demand. Specifically, sustainability or environmental demand can be classified in two main (but not mutually exclusive) groups: practice- or outcome-based. The practice-based demand tends to be easier to comply with as it can be fulfilled with yes/no questions, taking less time. Outcome-based demands focus on the measurement of specific results, require more complex tools and use agronomic data to calculate numerical values, yielding quantified results.

Market Demand Mechanisms

Table 2 documents the mechanisms by which sustainability markets drive demand for BMPs, for each category of initiative classified as having strong influence on market requirements for BMPs.

Table 2: Summary of Market Demand Mechanisms from Initiatives with Strong Influence on Market Requirements for BMPs

Category of Initiative	Description of Category	Mechanism of Market Demand
Sustainability guidelines or criteria	Expectations from specific agri-food associations or companies relating to sustainability practices	- Audits to verify compliance with regulation, the adoption of a BMP or the application of a given standard (e.g. water management on site). - Must comply with a specific certification or standard. - Some pilot programs to monitor/collect on-site data (soil, GHG emission, etc.), but no target to meet. - Mostly "practice-based" systems: must demonstrate the adoption of a specific BMP. - Some "outcome-based" systems but mostly voluntary or exploratory at the moment (pilot projects). - LCA is used to document high-level impacts and hot-spots through some of these guidelines.
Funding programs, support programs	Programs which provide financial support or any other type of support (e.g. professional guidance) to achieve a sustainability goal	- Must provide a management plan or demonstrate the adoption of a specific BMP.
Regulations	Laws or rules set by a government authority regarding a sustainability practice or environmental threshold	- Must meet specific offset quantification protocol.

Category of Initiative	Description of Category	Mechanism of Market Demand
Policies or frameworks	Codes or sets of guidelines (from agri-food associations or companies or other institutions) providing strategies or approaches to achieve compliance with regulations or standards	- Must demonstrate compliance with a given protocol or guideline. - Must demonstrate the adoption of a given BMP. - Must provide a management plan (which could be reviewed/audited). - Must endorse a specific protocol or industry standard - Must comply with a specific certification.

Conclusions

The following conclusions can be drawn from the Phase 2 analysis of demand for BMPs from sustainability markets:

- Markets are looking for compliance with guidelines and adoption of BMPs, as opposed to meeting specific targets
- Most market requirements are "practice-based", as opposed to "outcomes-based"
- Major players in the markets are building on existing tools and guidelines, rather than developing new ones. They are relying on the credibility and rigor of existing structures to develop their own programs. This can also be explained by the search for synergies, and the fact that markets are concerned about the proliferation of sustainability/environmental programs and requirements.
- Market demand is mostly being addressed on a commodity-by-commodity basis, and this can be explained by the fact that most sustainability and environmental issues are commodity-specific. Different stakeholders of a given commodity value chain (from farm to retail) are engaging in discussions to address these issues from a value-chain perspective.
- Although there is no strong market demand for outcome or quantitative performance results (e.g. specific measure of GHG emission reduction or water quality improvement), some initiatives are asking for "on-site" data collection and measurement. In this respect, the type of data that markets are looking for is mostly about inputs (e.g. energy use, pesticide use, water use) and outputs (e.g. quantity of manure, amount of wasted water) of farm practices, and not about quantitative measurement of BMP adoption.

Prioritization of BMPs

The primary purpose of the work completed for Phases 1 and 2 of the project was to build the information base necessary to prioritize the 33 BMPs of interest, listed in Phase 1, from the standpoint of AAF's On-Farm Stewardship Program. This is within the context that the scope of the Program may expand beyond water quality and inorganic waste, to include GHG emissions. As well, the interest of sustainability markets in BMP implementation may have high importance to the Program in the future.

Prioritization Process

As a result of these considerations, The AAF Project Management Team identified the following three prioritization criteria to be applied to the initial list of 33 BMPs analyzed in Phase 1:

- BMP potential impact on GHG emissions (from Phase 1)
- BMP potential impact on water quality (from Phase 1)
- Demand for the BMP from sustainability markets (from Phase 2)

These three criteria were given equal weight in the prioritization of BMPs.

The details of the prioritization process, using information from both Phase 1 and Phase 2, can be found in spreadsheet "BMP impact study Annex 1 Ph1-2 150416", sheet "Ranking". To help ensure that all the most important BMPs were captured, the three criteria above were applied to the 33 BMPs in three different combinations (ranking systems):

- (GHG impact + market demand)
- (Water quality impact + market demand)
- (GHG impact + water quality impact + market demand)

The analysis led to identification of 18 priority BMPs.

On spreadsheet "BMP impact study Annex 1 Ph1-2 150416", sheet "Ranking", the 33 BMPs are colour-coded as to their ranking based on:

- **All three ranking systems** – 12 BMPs rank in the top 15 under all three systems (green in the spreadsheet)(the number in parentheses indicates the BMP's overall ranking – from 1 to 18 - of the 18 priority BMPs):
  - **Soil Management**
    - BMP#6 -reduced tillage practices (rank #1)
    - BMP#8- crop rotation, incorporating perennial or pulse crops (rank #5)
    - BMP#7- cover crops (rank #4)
  - **Nutrient Management 4R**
    - BMP# 9- fertilizer application – source (rank #9)
    - BMP# 10- fertilizer application – rate (rank #10)
    - BMP# 11- fertilizer application – timing (rank #11)
    - BMP# 12- fertilizer application – placement (rank #12)
  - **Livestock Yards**
    - BMP# 16- setback distance for manure application in proximity to water bodies (rank #7)
  - **Manure Use/Management**
    - BMP# 13 - application rate based on testing and book values (rank #2)
    - BMP# 14- application method - conventionally tilled land (rank #3)
    - BMP# 15- timing of application for plant needs (rank #6)

- **Water bodies**
  - BMP# 28 -buffer zones for field crops (near riparian areas) (rank #8)

- **Water quality and market demand** – 5 additional BMPs are highly ranked (red):
  - **Water bodies**
    - BMP# 29- manage livestock access to water bodies and riparian areas (e.g. provide off-site watering) (rank #13)
  - **Livestock Yards**
    - BMP# 1 - siting - distance to nearest surface water body (rank #14)
    - BMP# 2- run-on control (rank #15)
    - BMP# 3- run-off control (rank #16)
    - BMP# 4 - catch basin management (rank #17)
- **GHG emissions and market demand** – 1 additional BMP received a fairly high rating (yellow)
  - **Water bodies**
    - BMP# 27 - Restoration of wetlands (rank #18)

Prioritization Findings

These 18 priority BMPs were fed into the second level of analysis in Phases 3 and 4 of the project.

Phases 3 and 4 – Review of Existing Models and Data

Phase 3 and 4 Objectives

Phase 3 involved an assessment of existing environmental and BMP modelling tools, with emphasis on their input requirements and methodologies. Of key interest was the applicability of each model to the context of agriculture in Alberta, and its potential to be modified to apply to the Alberta context.

The objective for Phase 4 was to identify and assess the data sources that could be used to populate actual tools of a future Alberta model to measure the impacts of BMPs. Two types of data source were studied:

1. Sources which could be used as direct input to a future model to describe specific on-farm conditions or activities
2. Life cycle inventory datasets that could be used to fill out missing data or to document background processes or off-farm activities.

Phase 3 and 4 Process

The Project Team started this task by reviewing the existing study on sustainability indicators, tools and reporting systems conducted on behalf of Alberta Agriculture and Rural Development (AARD). We completed this list with our own analysis of available tools.

Overall, thirteen environmental modelling tools were reviewed:

1. CoolFarm Tool
2. Feedprint
3. Holos
4. Field to Market ® FieldPrint Calculator
5. Canadian Field Print Calculator
6. Canadian Crop Carbon Footprint Lookup Tool
7. Egg Farmers of Alberta Environmental Footprinter
8. Nutrient Tracking Tool
9. Alberta Irrigation Management Model (AIMM)
10. Stewardship Index for Speciality Crops - Metric Calculator
11. WEBs GIS Tool
12. Sustainability Assessment of Food and Agriculture (SAFA) Tool
13. Dairy Farmers of Canada Environmental Footprinter and BMPs database

Table 3 outlines the fields documented by the Project Team for the assessment of existing models, including their associated datasets. The complete documentation is found in spreadsheet "BMP impact study Annex 2 Ph3-5 and factsheets 150416", sheet "Tools", columns A to O, which comprise the entire information base required for analysis of models and data sources.

Table 3: Documentation of Existing Tools and Datasets

Documented Fields	
Section	**Content (summary)**
General information	Objective, developers, format, costs, geographic coverage, types of user
Goal and Scope	Target audience, covered commodities, environmental indicators, scope, functionalities, ease of use
Modelling methods	Source datasets, methodology, Environmental factors, flexibility, benchmark capacity, transparency, overall quality of the model
Data input requirements	Primary data requirements (e.g. environmental conditions, crop management, carbon sequestration, livestock, etc.), default values, ease of use for the producer, units
Outputs	Type of results, type of analysis
Relevance for Alberta	Applicability, market recognition, commodities covered
Limitations	Limits of the model/tool
Covered BMPs	BMP by BMP analysis of coverage (for all 18 priority BMPs)

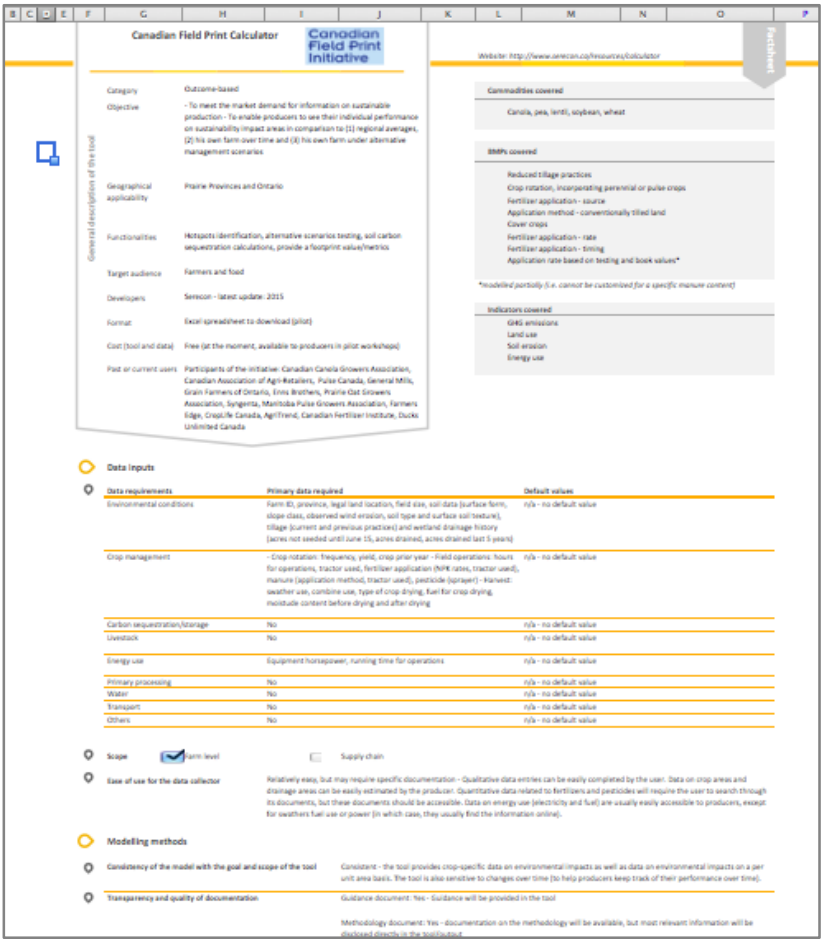
Regarding the "Relevance for Alberta" criteria, two things were considered:

1. The geographic scope of the tool (e.g., can the tool model specific Alberta conditions?)
2. The commodities covered. The Project Team prioritized sectors and commodities with input from the Project Management Team. Prioritized commodities and markets are presented in spreadsheet "BMP impact study Annex 2 Ph3-5 and factsheets 150416", sheets "Priorities commodities" and "Priorities markets".

A key aspect of this analysis was the assessment of the capacity of each tool to model each of the priority BMPs.

This information is available in full detail in the spreadsheet, but a standard descriptive fact sheet was developed to provide efficient documentation of this information for each of the reviewed tools.

Figure 3: Example of Descriptive Fact Sheet, Describing the Canadian Field Print Calculator



Phase 3 and 4 Findings

Just as there are different types of market demand, there are different types of tool. Specifically, sustainability tools can be classified into two main (but not mutually exclusive) groups: practice-based and outcomes-based.

- Practice-based tools aim to assess the activities or practices (e.g. agricultural management practices) implemented at the farm level, by benchmarking them against a set of good or expected practices. Most assessment frameworks and certification schemes used in agricultural production are driven by this kind of approach, making them easier to document at the organization level. This approach is exemplified by the Sustainability Assessment for Food and Agriculture (SAFA). Other widely used tools, such as the Environmental Farm Plan, are also practice-based tools.
- Outcomes-based tools assess the impacts (or outcomes) of activities carried out on the farm, by using characterization models to link inputs (e.g. fuel consumption, water use) to end-point impacts (e.g. climate change, water footprint). They usually require more quantitative data to operate and are more complex to use, but provide information on the intensity of the practices and their consequences. Examples of outcomes-based tools are the Egg Farmers of Alberta Footprinter and the Canadian Field Print Calculator. Many outcomes-based greenhouse gas evaluation tools have been developed recently.

Eleven of the 13 tools are outcomes-based, and one, the SAFA Tool, is practice-based. One tool, the Dairy Farmers of Canada Environmental Footprinter and BMPs database, falls into both the outcomes-based and practice-based categories. Five of the tools are dedicated only to GHG emissions accounting.

Review of Models

Table 4 presents a summary of the 13 tools reviewed, highlighting the scope (geographical applicability), priority commodities covered, and indicators covered.

Table 4: Summary of Reviewed Tools

Model	Scope	Priority Commodities Covered	Indicators
Outcome-based			
CoolFarm Tool (international)	Farm level	Barley, dry bean, potato, soybean, wheat	GHG
Feedprint (Europe)	Farm level	Swine, poultry, veal calves	GHG, LU, EU, E, A, FD
Holos (Canada)	Farm level	Wheat (durum, spring, winter), canola seed, live cattle, barley, potato, pulse crops (chickpea, dried bean, dried pea, fava bean, lentil, soybean), beef (fresh, frozen, chilled, incl. offal), pork (fresh, frozen, chilled, incl. offal), chicken	GHG, LU, SC
Field to Market FieldPrint Calculator (USA)	Farm level	Potato, wheat, soybean	GHG, LU, SC, C/B, WU, WQ, EU
Canadian Field Print Calculator (Canada – Prairies and Ontario)	Farm level	Wheat (durum, spring, winter), canola seed, pulse crops (dried pea, lentil)	GHG, LU, SC, SE, EU
Canadian Crop Carbon Footprint Lookup Tool (Canada – Prairies)	Farm level	Barley, canola	GHG

Model	Scope	Priority Commodities Covered	Indicators
Egg Farmers of Alberta Environmental Footprinter (Alberta)	Farm level and supply chain	Egg	GHG, LU, WU, EU, E, A, FD
Nutrient Tracking Tool (USA)	Farm level	Barley, bean, hay-grass, potato, wheat	NL
Alberta Irrigation Management Model (Alberta)	Farm level	Barley, canola, dry bean, fodder corn, hay-grass, potato, wheat	WU
Stewardship Index for Specialty Crops – Metric Calculator (USA)	Farm level	Dry pea, potato	SC, WU, EU, NU
University of Guelph's Canadian BMP Calculator (WEBs GIS Tool) – under development, Ontario for now	Farm level	All commodities	WU, WQ
Practice-based			
SAFA Tool (international)	Farm level and supply chain	All commodities	All except FD, O
Outcome- and Practice-based			
Dairy Farms + (Canada)	Farm level	None	GHG, LU, WU

GHG (GHG emissions); LU (Land use); C/B (Conservation/biodiversity); SC (Soil carbon); SE (Soil erosion); WU (Water use); WQ (Water quality); EU (Energy use); E (Eutrophication); A (Acidification); FD (Fossil fuel depletion); NU (Nutrient use); NL (Nutrient losses); O (Other indicators)

Review of Data Sources

Table 5 summarizes the potential data sources that could be used as direct input to a model to describe specific on-farm conditions or activities, and that were assessed by the Project Team. The detailed analysis is also presented in Column Q to Y of the spreadsheet "BMP impact study Annex 2 Ph3-5 and factsheets 150416", sheet "Tools". The spreadsheet "BMP impact study Annex 2 Ph3-5 and factsheets 150416", sheet "Data sources notes" also identifies the environmental indicators covered by these data sources.

The Team's overall conclusion regarding these data sources was that they are useful, but mostly for experts with specialist knowledge. They are too complex to be readily used by farmers. They are useful for purposes of updating the existing tools.

Table 5: Summary of Data Sources

Data Source	Description
AgroClimatic Information Service (ACIS)	"Interactive tool that helps producers, farm consultants, and researchers to see Alberta weather forecasts, browse over 10000 maps of Alberta weather and Alberta climate related information, and access near real time station data from over 350 meteorological stations operating in the province of Alberta"
Water Quality in Alberta's Irrigation Districts	"Alberta Agriculture and Rural Development and its partners (Irrigation Council, Alberta Irrigation Projects Association and Agriculture and and Agri-Food Canada) initiated a five-year study (2011-2015) to assess the water quality of Alberta's irrigation districts. Approximately 90 sites within the 13 irrigation districts are sampled four times per year during the irrigation season. Samples are analyzed for up to 160 water quality parameters including nutrients, salts, metals, pathogens and pesticides."
Agricultural Water Survey (AWS)	"The Agricultural Water Survey is conducted to gather information on irrigation water use, irrigation methods and practices, and sources and quality of water used for agricultural purposes on Canadian farms. The results will help farm operators, governments and the Canadian public gain a better understanding of the demand for water and how it is used on Canadian farms."

Data Source	Description
Assessment of Environmental Sustainability in Alberta's Agricultural Watersheds Project	"To assess temporal and spatial patterns in water quality in watersheds with agricultural activity. Twenty-three watersheds were selected to encompass the range of agricultural intensities throughout the province including low agricultural intensity watersheds, watersheds already subject to high intensity farming, watersheds with the potential for intensified agriculture, and those draining irrigation return flows."
Manure application effects on soil and groundwater quality under irrigation in southern Alberta	- "To determine the effects of repeated application of cattle manure on soil quality, shallow groundwater quality, and crop production on two soil types under irrigated conditions - Based on the results, to make appropriate recommendations for the management of manure application on land to minimize or prevent detrimental effects on soil and groundwater resources"
Relationships between Soil and Runoff Phosphorus in Small Alberta Watershed	- To determine the field-scale relationship between soil-test phosphorus (STP) and runoff total phosphorus (TP) and dissolved reactive phosphorus (DRP) from field-sized catchments or "microwatersheds" under spring snowmelt and summer rainfall conditions in Alberta - To compare the relationship with the Edge-of-field Phosphorus Export Model (EFPEM) for DRP (Wright et al. 2003)
Trends in residual soil nitrogen for agricultural land in Canada, 1981-2006	- Determine the annual residual soil nitrogen (RSN) using the Canadian Agricultural Nitrogen Budget model (CANB v3.0) and develop a RSN indicator to provide an "estimate of the amount of "unused" nitrogen that remains in the soil at the end of the cropping season"
The National Soil DataBase (NSDB)	- Provides soil, landscape and climatic data for all of Canada - "Serves as the national archive for land resources information that was collected by federal and provincial field surveys, or created by land data analysis projects"
Environmental Sustainability of Canadian Agriculture	- To develop "a set of science-based agri-environmental indicators that integrate information on soils, climate and topography with statistics on land use and crop and livestock management practices" (indicators: soil, water and air quality, farm land management and resource use efficiency in the food and beverage industry) - To provide "valuable information on the environmental risks and conditions in agriculture and how these change over time" - To develop indicators that are "sensitive to the considerable differences in conditions and in the commodity mix across Canada"

The Project Team also assessed LCI and LCA databases which could be used to fill in missing data, or for modelling of background processes or off-farm activities. These are summarized in Table 6. The Project Team concluded that these databases contain valuable data for some of the modelling required by a new BMP impact measurement tool. However specific expertise is again needed to utilize this data. As well, the data in LCI and LCA databases is generally limited to average or aggregated values. This might represent a challenge if the objective is to model specific and on-site BMP benefits.

Table 6: Summary of LCI/LCA Databases

Name	Authors	Sources/website
Agri-footprint	Pré Consultants	https://www.pre-sustainability.com/agricultural-lca-database-available-simapro
World Food **LCA**	Quantis International	http://www.quantis-intl.com/files/2714/0626/8848/WFLDB_MethodologicalGuidelines_20140723_v2.0.pdf
AGRIBALYSE	ADEME	http://lcacenter.org/lcafood2014/papers/87.pdf

Name	Authors	Sources/website
LCA Food Database	2.-0 LCA Consultants	http://www.lcafood.dk/
Water Footprint Network database	Water Footprint Network	**waterfootprint**.org
LCA Commons	USDA	http://www.lcacommons.gov/about
Swiss Agricultural Life Cycle Assessment	EPFL	http://www.agroscope.admin.ch/oekobilanzen/01199/index.html?lang=en
Ecoinvent database	Ecoinvent	http://www.ecoinvent.org
Gabi database	Thinkstep	http://www.gabi-software.com/databases/

Potential to Model Priority BMPs

At this stage of the project, through the Phase 3 and 4 tasks, the Project Team had compiled a large amount of data describing existing models and datasets, and the capacity to model commodities and indicators of importance in Alberta. The significance of this compilation of data is that it comprises a database that provides the ability to

1. Identify the most important BMPs for the On-Farm Stewardship Program to support (Phases 1 and 2), and
2. Identify the existing capacity (and gaps) to model these BMPs (Phases 3 and 4)

With this, the Project Team took the data from all four phases of the project, and turned to the central research questions of the project:

1. Can the tools and data available model the top-priority BMPs identified in Phases 1 and 2?
2. If so, can users readily compare a scenario where the BMP is in place with another scenario without the BMP, and so measure the impact of the BMP?

Spreadsheet "BMP impact study Annex 2 Ph3-5 and factsheets 150416", sheet "Analysis – by BMP" summarizes the capacity of each tool assessed to model each of the priority BMPs. Columns B-C present the priority BMPs and a short description. Columns D to P present each tool's position regarding the two questions above, while columns Q and R summarize the conclusions from a BMP point of view.

Table 7 summarizes the capacity of existing tools and data to model the priority BMPs identified in Phases 1 and 2. The numbers in parentheses represent the unique ID for each BMP used in the spreadsheet.

Table 7: Capacity to Model Priority BMPs

High capacity to model	Moderate capacity to model	Low capacity to model
Soil Management – reduced tillage (BMP # 6)	**Livestock Yards** - run-off control (BMP # 3) - catch basin management (BMP # 4)	**Livestock Yards** - run-on control (BMP # 2) - siting - distance to nearest surface water body (BMP #1)
Nutrient Management – 4R - fertilizer application – source (BMP #9) - fertilizer application – rate (BMP # 10)	**Soil Management** - cover crops (BMP # 7) - crop rotation (BMP # 8)	**Manure Use/Management** - application – timing (BMP # 15)
Manure Use/Management - application rate (BMP # 13)	**Nutrient Management – 4R** - fertilizer application – timing (BMP # 11) - fertilizer application – placement (BMP # 12)	**Water Bodies** - wetland restoration (BMP # 27) - buffer zones for field crops (near riparian areas) (BMP # 28)
	Manure Use/Management - application method (BMP # 14) - application – setback from water bodies (BMP # 16)	
	Water Bodies - livestock access /off-stream watering (BMP # 29)	

Analysis of Tools

The Project Team's overall findings from the Phase 3 assessment of existing tools are as follows:

- Only five of the 13 tools assessed are applicable to Alberta (six if we include WEBs GIS, which is in development and very promising)
- All the priority BMPs and commodities cannot be modelled using a single tool
- Water quality BMPs are not well covered by existing tools
- Only one tool – WEBs GIS – includes economic modelling, while Holos is working toward including it

The overall conclusion from Phases 3 and 4 is that each of the tools assessed has its own scope, in terms of indicators and commodities, and each has its own strengths and weaknesses. There is no obvious, single-tool answer to the problem of modelling BMP impacts.

The top three tools (based on geographical scope, covered commodities and capacity to model priority BMPs) are:

- Canadian Field Print Calculator
- Holos
- WEBs GIS

WEBsGIS seems to offer very promising potential in terms of water quality modelling, and AAF should follow its development closely.

Table 8 is an extract from the spreadsheet "BMP impact study Annex 2 Ph3-5 and factsheets 150416", sheet "Analysis – By Tool" showing how the top tools can model some of the priority BMPs.

Table 8: Modelling of Priority BMPs by Top Tools

Tool Name	Holos	Canadian Field Print Calculator	WEBs GiS
Description	To estimate GHG emissions and help users identify ways to reduce farm emissions.	To meet the market demand for information on sustainable production To enable producers to see their individual performance on sustainability impact areas in comparison to (1) regional averages, (2) his own farm over time and (3) his own farm under alternative management scenarios	To evaluate the economic costs, water quantity and quality benefits and cost effectiveness of agricultural BMPs across a watershed. The tool, which was designed to be user-friendly for farmers, watershed managers and other conservation practitioners also allows to identify and target key areas with the highest potential impacts.
Indicators	GHG, LU, SC	GHG, LU, SC, SE, EU	WU, WQ
Format	Online calculator and Excel version available for offline use	Offline tool	Online calculator (to be developed) and Excel version available for offline use
Modelling BMPs capacity	6, 7, 8, 9, 10, 13 and partially 28 (future version should be able to model 11, 12, 15)	6, 7, 8, 9, 10, 11, 14, and partially 13 and 15	Impact on watershed only, but of the following BMPs: 3, 4, 6, 7, 9, 10, 11, 12, 13, 14, 15, and partially 1, 16, 27, 28 , 29
Applicability to Alberta context	Applicable. The model is developed for a Canadian context with a level of precision to the ecozone.	Applicable. The tool covers the Prairie Provinces and Ontario.	Ontario (for now)
Covered commodities	Wheat (durum, spring, winter), canola seed, live cattle, barley, potato, pulse crops (chickpeas, dried bean, dried pea, fava bean, lentil, soybean), beef (fresh, frozen, chilled, incl. Offal), pork (Fresh, Frozen, Chilled, incl. Offal), chicken	Wheat (durum, spring, winter), canola seed, pulse crops (dried pea, lentil)	All commodities

BMP Modelling – Case Study

Two key questions must be addressed in order to make decisions as to the best approach to modelling BMP impacts in the present agriculture industry environment:

1. What are the roles and interests of the different stakeholders, i.e. farmers, industry associations and policy makers?
2. How should BMP modelling tools be used?

The following case study explores the roles and responsibilities of the different stakeholders, to illustrate the potential uses of the information compiled in this feasibility study. The BMP reduced tillage is used as an example.

Table 9: Potential Use of Models and Data, by Stakeholder

	Farmers	Industry Associations	Policy Makers
Key Responsibilities	Profitability, long-term soil fertility	Ensure cost-efficiency and competitiveness of members, including in terms of sustainability	Promote a competitive and sustainable agriculture and food industry
Capacity	Farmers have the primary data for most tools, e.g., for reduced tillage: ▪ Field location ▪ Soil condition ▪ Current and past management ▪ Fuel use Farmers can directly use models such as Holos or Canadian Field Print Calculator, to measure impacts on CO_2e emissions	Associations generally have the capacity to collect information from their members, and this data can be used to measure the global performance of their members Associations have access to experts familiar with some or all of the tools reviewed here	Policy makers can propose and apply regulations, guidelines Policy makers can promote good practices through awareness campaigns, pilot testing, financial incentives Policy makers have access to expertise Policy makers can collect data and generate statistics at provincial level
Challenges	CO_2e reductions may not motivate practice changes Considerations such as costs, risk management, will likely influence farmers' decisions more strongly The intrinsic uncertainty of the tools - +/- 10, 20, 50% - different tools and data give different results		

Use of Tools

This case study illustrates several important points about the use of tools to model BMP impacts:

- Tools can be used at the farm level to calculate benefits of BMPs such as reduced tillage, but this information is unlikely to drive change in most cases
- For most tools, very little data is needed to model impacts of reduced tillage, but accuracy is not high

- It is feasible to calculate global benefits, by aggregating data from a group of farmers
- The models could be used to prioritize the BMPs according to the magnitude of their benefits, using a group of farmers, e.g. coordinated by producer associations or provincial governments
  - Associations or policy makers are better equipped than farmers to perform this work, owing to their access to expertise and data (more cost-effective)
  - Based on the results of this exercise, incentives can be developed and managed by associations or the province, to overcome barriers to change at farm level (addressing, e.g., knowledge, costs, risk management)
  - Due to high uncertainty in the calculation of the benefits of reduced tillage (+/- 40% according to Holos), average results at the association or provincial level would be more relevant than results for individual farms

Conclusions

This Feasibility Analysis has comprised two levels of analysis. The first (Phases 1 and 2) involved prioritizing the identified list of BMPs according to

- Demand for each BMP from sustainability markets
- Environmental impacts of each BMP (on GHG emissions and water quality)

The second level of analysis (Phases 3 and 4) systematically assessed existing tools and data sources for the capacity to model the 18 priority BMPs, for Alberta's major commodities.

The analysis provides valuable information on the relative importance of the BMPs assessed, and on the existing capacity to model them. However, more importantly, the project has generated a database to support analysis of BMP importance and modelling capacity. This allows for analysis of additional BMPs, models and datasets in the future. Thus the key output of the project is a tool to prioritize BMPs and assess the feasibility of modelling them.

The following are the specific conclusions drawn from the prioritization of BMPs performed in Phases 1 and 2, of the project, and the second-level analysis conducted in Phases 3 and 4.

Of the 33 BMPs assessed, the following 4 seem to offer the most potential for further consideration from AAF, since they were identified as priority BMPs (from an environmental and market demand perspective) AND their benefits can be modelled by some of the tools reviewed:

1) Soil Management - reduced tillage practices (BMP#6)
2) Nutrient Management – 4R - fertilizer application – source (BMP#9)
3) Nutrient Management – 4R - fertilizer application – rate (BMP#10)
4) Manure Use/Management - application rate based on testing and book values (BMP#13)

Spreadsheet "BMP impact study Annex 2 Ph3-5 and factsheets 150416", sheet "Analysis – By Tool" provides detailed information on how these BMPs can be modelled by the different tools.

Table 7 also provides a complete overview of the capacity to model the priority BMPs.

Other main conclusions from the analysis are:

- Water quality impacts of individual BMPs are very difficult to model (scientific research on which to base such modelling is lacking)
- So far, market demand for BMPs is focused more on adoption of specific BMPs than on measurement of BMP impacts/performance on the farm

- There are existing tools capable of modelling BMP impacts, but there is no "silver bullet" solution to modelling the impacts of all the identified priority BMPs. Rather, combinations of tools will be needed to cover the relevant ranges of commodities and environmental indicators.
- BMP impact modelling capacity can provide value to policy makers, as illustrated by the case study above:
  - BMP impacts can be modelled in order to prioritize BMPs on the basis of the magnitude of their environmental benefits, by aggregating results from multiple farms
  - Such a prioritization can be used to identify key BMPs to target with incentives and education programs
  - Average results from BMP impact modelling (which could readily be coordinated by government) would be more relevant than results from individual farms, given the high level of uncertainty in calculations for individual farms

Recommendations

The analysis conducted for this study points to several areas where effort by Alberta Agriculture and Forestry can be targeted to leverage existing modelling capacity to improve information on BMP impacts on environmental sustainability. This, in turn, has strong potential to provide for more refined and effective delivery of incentives and information by AAF to farmers.

Based on the information collected, and the analysis conducted throughout this Feasibility Study, the Project Team does not recommend the development of a new model. Considerable modelling capacity is already in place, and should not be duplicated. Rather, the Project Team recommends developing a toolbox from existing tools, as a more cost-effective way of supporting farmers.

The Project Team recommends that the On-Farm Stewardship Program and Alberta Agriculture and Forestry build on the findings of this Feasibility Study by investing effort in the following:

- Development of roadmaps and toolboxes to identify the best combinations of data and tools for modelling of specific commodities and BMP impacts. This should include providing guidance and support for the development of regionalized data, as well as for validation of assumptions and models. This will provide guidelines that provide for application of consistent data and assumptions by different model users. These toolboxes could combine existing tools and data. This Feasibility Analysis has generated the process and a database (enabling analysis of BMP importance and modelling capacity) to support these objectives.
- Adaptation and regionalisation of existing tools (e.g. Holos, WEBs GIS) to the Alberta context
- Support the inclusion of modelling of additional commodities by existing tools (e.g. Canadian Field Print Calculator)
- Support further research and adaptation of existing tools to improve their capacity to model BMP impacts on water quality. This is necessary to address, e.g., the site-specificity of BMP impacts on water quality, and the present lack of research on individual BMP impacts on water quality.
- Support further research and adaptation of existing tools to improve capacity to model BMP impacts on economic benefits