# REPORT OF THE CONSULTATION WORKSHOP ON ENVIRONMENTAL INDICATORS FOR CANADIAN AGRICULTURE

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## CONTENTS

ACKNOWLEDGEMENTS i

1.0 INTRODUCTION 1

2.0 WORKSHOP HIGHLIGHTS 2

3.0 WORKSHOP CONTEXT 3
- 3.1 The Agri-Environmental Indicator Project 3
- 3.2 Objectives and Structure of the Workshop 3

4.0 WORKSHOP RESULTS 5
- 4.1 Task One 5
- 4.2 Task Two 7
- 4.3 Tasks Three & Four 8
  - 4.3.1 Water Quantity Indicators 8
  - 4.3.2 Land & Soil Resources Indicators 12
  - 4.3.3 Genetic Diversity Indicators 15
  - 4.3.4 Wildlife Habitat Indicators 17
  - 4.3.5 Air & Climate Indicators 19
  - 4.3.6 Agricultural Inputs Indicators 20
  - 4.3.7 Water Quality Indicators 23
- 4.4 Task Five 26

5.0 REFERENCES 28

6.0 ATTACHMENTS 29
- 6.1 Workshop Programme 30
- 6.2 Workshop Participants 32
- 6.3 Members of the Environmental Indicator Working Group of Agriculture and Agri-Food Canada 37
- 6.4 Workshop Breakout Group Structure 38

**CONTENTS** (cont'd)


| | | |
|---|---|---|
| 7.0 | ENVIRONMENTAL INDICATORS DISCUSSED AT THE WORKSHOP | 39 |
| | Water Quantity Indicators | 40 |
| | Agriculture Land and Soil Indicators | 48 |
| | Genetic Diversity Indicators | 55 |
| | Wildlife Habitat Indicators | 61 |
| | Air and Climate Indicators | 66 |
| | Agricultural Inputs Indicators | 72 |
| | Water Quality Indicators | 77 |

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# 1.0 INTRODUCTION

Environmental sustainability in Canadian agriculture has received increased attention as a policy issue in recent years. The 1989 Agri-food Policy Review (Agriculture Canada, 1989) identified environmental sustainability as a key policy goal for the agri-food sector. The sustainable agriculture component of the federal Green Plan (Government of Canada, 1990), the Canadian Agricultural Services Coordinating Committee, (now called Canadian Agri-Food Research Council), the Science Council of Canada (1992) and the House of Commons Standing Committee on Agriculture (1992) have reinforced this direction and given expression to it.

The agricultural sector's historical focus on soil degradation and impacts on productivity has evolved to encompass broader public concerns about the relationship between agricultural production and environmental issues such as water quality, climate change and preservation of biodiversity. Decision-makers at all levels are responding through various initiatives, programs and policies that range from the farm level to the national and international levels.

Environmental performance indicators for agriculture have been identified as important tools both for helping design policy initiatives and for evaluating their effectiveness. For advice on how to develop a useful set of agri-environmental indicators for Canadian agriculture, Agriculture and Agri-Food Canada invited some 80 participants to a consultation workshop in Aylmer, Quebec on 6 & 7 December 1993.

Collectively, the participants represented a diverse range of interests and organizations, including the federal government, most provincial governments, industry organizations, various nongovernmental organizations and the academic community.

This report summarizes the discussions and results of the workshop. Section 2 lists the key highlights of the discussions. Section 3 describes the larger context in which the workshop took place, as well as workshop objectives and structure. Section 4 presents the results and conclusions reached by participants. Additional information of interest is included in the attachments in Section 6. Section 7 lists and describes the agri-environmental indicators reviewed and discussed at the workshop.

## 2.0 WORKSHOP HIGHLIGHTS

Participants at the consultation workshop on agri-environmental indicators discussed how a comprehensive set of indicators to measure the sustainability of Canadian agriculture might be developed. The main points which resulted from these discussions are as follows:

- Participants emphasized the importance of developing relevant environmental performance indicators for agriculture and recommended that Agriculture and Agri-Food Canada continue to play a lead role in this area.

- The issues used to group the potential indicators were all considered relevant. The issues were ranked by perceived importance, and several new issues were identified for consideration (see section 4.1).

- Many participants suggested integrating the issues approach used for organizing the indicators with a more comprehensive agri-environmental assessment framework. The frameworks used in the United States and Australia were identified as being potentially relevant to Canada (see section 4.2).

- Participants made another suggestion: that the inclusion of indicators which track sustainable production and sustainable management practices (i.e. stewardship) be considered in the development of an agri-environmental assessment framework.

- Participants agreed that indicators should be regionally sensitive and identified the farm as a basic unit for collecting some data. Farm-level data could then be aggregated as needed to suit the needs of particular users. Agro-ecological land areas and watersheds were suggested as possible units for data aggregation.

- Participants reviewed each of the potential indicators and commented on their relevance and possible improvement and development. Indicators for each issue were ranked in order of perceived importance (see section 4.3). In some cases, participants suggested combining related indicators to form broader composite indicators that would provide more useful information that any single indicator.

- The evolution and continued implementation of the project was discussed. Participants suggested that:

  - a strategic plan be developed which identifies a consultation process, a core set of indicators for development, and long-term project objectives.

  - consultations with stakeholders; be ongoing throughout the project;

  - partnerships be encouraged for developing indicators, and a variety of options be considered for reporting information to users.

## 3.0 WORKSHOP CONTEXT

This section describes the objectives of the agri-environmental indicator development project and the context and goals of the workshop.

### 3.1 The Agri-Environmental Indicator Project.

The general objectives of the agri-environmental indicator development project, initiated in 1993 by Agriculture and Agri-food Canada, are to:

- develop a capability for evaluating the agricultural sector's environmental performance, in particular at the national level;
- provide agri-food decision-makers and stakeholders with succinct information on key environmental sustainability trends in their sector.
- facilitate the integration of environmental considerations into the sector's policy-making, programming and planning processes, by providing relevant information .

The specific objective of the project is to develop a set of agri-environmental indicators which relate to the general objectives. To reach this objective, the project will stimulate, coordinate and focus work in relevant areas.

The project seeks to build on and integrate both past and ongoing research and analytical work in such areas as land management evaluation and biological resources research. The development of agri-environmental indicators is consistent with the policy directions and/or recommendations of the Federal-Provincial Agriculture Committee on Environmental Sustainability (Agriculture Canada, 1990), the federal Green Plan (Government of Canada, 1990), the Canadian Agricultural Services Coordinating Committee (now called Canadian Agri-Food Research Council), the Office of the Auditor General (1993), the Science Council of Canada (1992), and the House of Commons Standing Committee on Agriculture (1992).

Work in 1993 focused on both developing a framework through which relevant issues and policy assessment questions were specified (Agriculture Canada, 1993) and identifying potential indicators of agri-environmental sustainability in relation to these issues and policy questions. The December 1993 consultation workshop was essential to this identification phase. An international workshop on sustainable land management, held in Lethbridge, Alberta in June 1993 (Dumanski, 1994), also focused on identifying potential indicators for sustainable land management.

The results of the workshop will be used to help identify a core set of agri-environmental indicators for development in 1994 and beyond. In identifying such a set, the rankings assigned to the potential indicators will have to be weighed against other factors such as cost, feasibility, further scientific validation and the results of additional consultations.

In general, the period prior to 1996 will focus largely on developing indicators and preparing interim or progress reports. Inter-agency collaboration and consultations will be ongoing throughout this period. Periodic reporting of the indicators could begin following the analysis of data from the 1996 Census of Agriculture, although it may be possible to report results for some indicators before then.

### 3.2 Objectives and Structure of the Workshop

Two general objectives were identified for the workshop:

- To exchange, discuss and clarify ideas and approaches to developing policy-relevant indicators of environmental sustainability in Canadian agriculture.

- To provide scientific and policy advice to Agriculture and Agri-food Canada on the development of policy-relevant indicators of environmental sustainability in Canadian agriculture.

The workshop included both plenary and breakout group sessions (see attachment 6.1 for workshop program). Participants were divided into seven breakout groups, with each group asked to focus on a specific agri-environmental issue and

- review the specific potential indicators identified for that issue, comment on their utility and information content, provide suggestions on their improvement and development, and rank the indicators in order of priority for development;

- identify other issues which should be considered and point out additional indicators which should be developed;

- discuss the interrelationships between the indicators and suggest how they could be grouped to emphasize and demonstrate these linkages and relationships;

- provide advice on developing a comprehensive set of indicators;

- identify and discuss potential next steps in the project, including opportunities for collaboration;

- reflect their professional and/or institutional interests in the area of agri-environmental indicator development and identify work planned or underway which is complementary with the overall goals of the project.

Workshop participants received a workbook which identified five tasks to be completed and areas in which comments and responses were to be recorded. The results are summarized in section two of this report and presented in detail in section four.

## 4.0 WORKSHOP RESULTS

This section presents the discussions and results of the workshop by task.

### 4.1 TASK ONE: to review and provide guidance on selecting issues where agri-environmental indicators are needed.

The agri-environmental issues for which potential indicators were selected are largely based on the issues identified in 1990 by the Federal-Provincial Agriculture Committee on Environmental Sustainability. These issues are:

- agricultural land resources
- air and climate
- surface and groundwater quality
- water quantity
- wildlife habitat
- genetic diversity
- agricultural inputs.

The scope of these issues is broad, and there are numerous linkages and relationships between them.

Workshop participants were asked to:

- identify any issues or areas which should be added and/or dropped, and provide a brief rationale for doing so;

- rank the agri-environmental issues considered in this project in order of perceived importance for agri-environmental indicator development.

**Main points**

- All key issues were considered relevant and thus retained.

- Participants suggested grouping wildlife habitat and genetic diversity together under the heading "biodiversity". The possibility of grouping water quantity and air and climate together was also discussed but rejected.

- Three new areas were identified for indicator development: socio-economic-environment linkages, waste management, and food quality/safety.

- Participants gave highest ranking to agricultural land and soil resources and to surface and groundwater quality. Water quantity, wildlife habitat, genetic diversity and air and climate received medium ranking. The only issue that received a low ranking was agricultural inputs. A summary of the rankings is provided in Table 1.

**TABLE 1:** Ranking Of Issues Identified For Agri-environmental Indicator Development.

| ISSUE | RANK |
|---|---|
| Agricultural Land Resources | HIGH |
| Surface & Groundwater Quality | HIGH |
| Water Quality | MEDIUM |
| Air and Climate | MEDIUM |
| Wildlife Habitat and Genetic Diversity | MEDIUM |
| Agricultural Inputs | LOW |

**Rationale for issue rankings**

**Agricultural Land Resources**

- This issue was ranked as a high priority by the majority of participants. It was seen as a key area of agri-environmental sustainability because preservation and conservation of soil resources is the basis for sustainable agriculture. The land and soil issue was also seen as connected to many of the other issues. Thus, sustainable land management will help address both on-farm and off-farm environmental concerns such as water quality and loss of biodiversity.

**Surface and Groundwater Quality**

- Virtually all participants felt that this was also a high-priority issue because it is a major natural resource used and affected by agriculture. The public is very concerned about this issue, particularly as it concerns water contamination by farm inputs and wastes. Water quality can provide a broad measure of the environmental sustainability of various farm production and management systems.

**Water Quantity**

- This issue received medium ranking and was noted to be of particular importance to prairie Canada where water availability can be a limiting factor for agriculture. The water quantity issue was also discussed in terms of concerns about water excess and surplus in other regions of Canada. The manner in which water is utilized and managed can provide a signal of environmental sustainability.

**Wildlife Habitat and Genetic Diversity (Biodiversity)**

- Participants recommended combining these two issue categories under a new heading, **biodiversity,** which received a medium ranking. Biodiversity was seen as a vital issue to the long-term viability of agriculture (i.e. genetic diversity) and an area where severe impacts have been documented (e.g. loss of native grasslands and wetlands). The potential for agriculture to make a significant contribution toward conserving biodiversity was also recognized.

**Air and Climate**

- This issue received a medium ranking, with climate change and ozone depletion identified as the major concerns, followed by tropospheric air pollution from agriculture. The role of the agriculture sector in influencing climate change and ozone depletion, was discussed, as were the potential impacts of these problems on agriculture. There is also an important linkage to the climate change convention in terms of the sector's role as either a net source or sink of greenhouse gases.

**Agricultural Inputs**

- Overall, agricultural inputs (energy, fertilizer, pesticides) was given a low ranking as an issue onto itself. Many participants saw this issue as a subset of other issues and suggested including it in, or linking it to, other areas to make it meaningful. Agricultural inputs was interpreted to represent "causes" while many other indicators attempted to measure effects. However, the strong link between agricultural input use and public concerns about the environmental effects of agriculture was recognized.

**<u>Additional issues and recommendations</u>**

- Several additional issues were identified as areas to be considered for indicator development:

  **Waste Management:** This encompasses manure use and contamination. Its emergence came about because it had not included as a part of the agricultural inputs issue.

  **Food Quality/Safety:** This was perceived to be an important issue for the agricultural sector as well as a pubic concern. The linkages between food quality and input use, and food processing and impacts on water quality, were noted (Note: the issue of pollution from food processing will be considered in the report of the Federal-Provincial Agriculture Committee on Environmental Sustainability [Agriculture Canada, 1990]).

**Socioeconomic Change:** It was suggested that consideration be given to developing socioeconomic indicators that are related to the environment (e.g. change to farm size and structure) because such changes can strongly influence environmental sustainability.

**4.2 TASK TWO:** to review and provide guidance on grouping and linking the issues and indicators discussed at the workshop

Participants were asked for their views and suggestions on the most appropriate approach for organizing the indicators in this project in a comprehensive manner (by issue, by assessment framework, by linking indicators to specific objectives, some combination of above, etc.).

**Main points**

- No single consensus developed around a particular organizational framework or approach. Recommendations focused on linking the indicators either by issue, by means of some other assessment framework, or through a combination of both.

- Many participants felt it would be useful to move beyond an issue-by-issue approach and toward other systematic reporting frameworks used in other countries. The Australian and American models, or some combination of both, were cited as examples of particular relevance to Canada.

- Participants discussed spatial approaches to organizing data and reporting the indicators e.g. the farm unit, eco-regions and watersheds.

**Results**

**Issue Approach**

- This approach for grouping the indicators was favoured by many participants because it is simple, understandable, and easily communicated to policy makers.

**Pressure-State-Response (PSR) Framework**

- The PSR framework was supported on its ability to organize indicators on a cause-effect basis. However, concerns were expressed regarding limitations in data availability and scientific understanding. These limitations could restrict the interpretation of the indicators because rigorous cause-effect linkages are often difficult to establish.

**Link To Objectives**

- This approach was seen as very relevant to policy and was emphasized as particularly useful in cases where clear agri-environmental objectives are in place. Indicators can track movements towards or away from these objectives. Some participants suggested that clear environmental objectives should be set before indicators are selected.

  However, one disadvantage of focusing solely on an objectives-driven framework stands out: important signals of ecological change can be overlooked for phenomena in which no policy or scientific objectives have been established.

**Spatial Frameworks**

- Participants discussed spatial frameworks to be used for analyses. The farm unit was seen as a basic unit for collecting some data, which could then be aggregated using an appropriate ecoregion land classification scheme based on landform, physiography and climate or watershed. Such an approach would be sensitive to regional diversity in agricultural practices and environmental attributes. It was envisioned that a first linkage would be established with a designated land-based region and then, as client needs dictate, the data could be aggregated to encompass larger areas.

**Other Frameworks**

- Participants discussed other agri-environmental indicator frameworks of potential relevance for Canada: in particular, the Australian framework and the American framework.

- The Australian approach (Hamblin, 1992) identifies potential indicators for agriculture in three areas: management, production, and quality of the resource base. The approach is comprehensive in that linkages between relevant environmental and socio-economic changes in the agricultural sector are identified.

- The framework being used in the United States by the agro-ecosystem health component of EMAP, the Environmental Monitoring and Assessment Program (Heck *et. al.*, 1992) seeks to formulate indicators that relate to three broad societal values for agriculture: supply of agricultural commodities (productivity), quality of natural resources (air, water and soil) and conservation of biological resources (biodiversity). Assessment endpoints have been identified for relevant indicators. This approach received support because it links productivity to the quality of natural resources and the conservation of biodiversity.

**4.3 TASKS THREE AND FOUR:** for Tasks 3 and 4, each breakout group was assigned an issue and asked to focus on the potential indicators identified for it.

In Task 3, participants were asked to consider the following factors for each indicator:

- how its relevance and utility to policy-making might be improved;

- how its information content might be enriched;

- the feasibility of developing the indicator, whether the required data are available, and if they are available, from whom;

- recommendations on immediate next steps for developing the indicator.

In Task 4, participants were asked to identify those indicators which they felt best addressed the issue area they had been assigned, and to rank the indicators in order of priority for development.

**RESULTS**

The results of both tasks are reported by issue area. The following section summarizes the comments on specific indicators for each issue (results of task 3), and gives the ranking assigned to those indicators (result of task 4).

### 4.3.1 WATER QUANTITY INDICATORS

Participants considered the potential water quantity indicators in terms of measuring sustainable water use and management, and adapting agriculture to water supply conditions (deficits and surpluses).

## Review of Individual Indicators

**Indicator: Sustainable Yield Index for Surface Water** (Appendix 7.1-6)

- Participants noted this indicator's potential for providing early warning of unsustainable water use and its consequent relevance to policy. However, they also noted potential difficulties in linking the indicator directly to agriculture because other sectors also extract water for various uses.

- This indicator can be enhanced by developing indexes for selected watersheds in the country and by selecting appropriate representative locations for stream flow monitoring. Interpretation of the indicator will require that actual extraction rates be compared against estimated sustainable water yield.

- Developing the indicator was seen as feasible, at least for river basins where flow monitoring networks and data bases are in place. Data are available from Environment Canada (Water Survey of Canada) and provincial water resource agencies responsible for river stream flow monitoring.

- As a possible next step, participants suggested conducting specific case studies, possibly targeted on predominantly agricultural watersheds in water-scarce areas. Appropriate baseline/benchmark flow levels should be established for developing or calculating an index of sustainable water yield. Further, participants pointed out that the establishment of credible protocols depends on coordination and standardization.

**Indicator: Sustainable Yield Index for Groundwater** (Appendix 7.1-7)

- As with the sustainable yield index for surface water, this indicator was seen as very relevant to policy and long-term sustainability. However, similar difficulties in linking it directly to agriculture were expressed.

- Development of the indicator was seen as possible, but only in the longer term. Reliable measurement techniques to quantify the groundwater resource have not been established, and long-term data (minimum of 10 years) are needed to adequately assess sustainability of use. An inventory of groundwater aquifers is required , but it may involve considerable effort. Participants expressed concern about the cost of collecting reliable data from all aquifers, especially if they are to be site specific. On the prairies, however, cooperation with provincial authorities may yield up-to-date inventories of groundwater and its use.

- Selected case studies were seen as a possible way to start developing this indicator, to test methodology, to assess feasibility and to conduct cost-benefit analysis. Priority should be placed on the more heavily used aquifers located in predominantly agricultural regions.

**Indicator: Relative Irrigated Area by System Efficiency (Appendix 7.1-9)**

- Participants perceived this indicator as relevant to policy, particularly in areas where water availability is limited and development and distribution costs are high. It was also seen as a management-related indicator which might encourage water use efficiency and as applicable to regional and local assessment. Many felt that this indicator may be useful for international comparisons.

- To develop the indicator, it may be necessary to identify standards for calculating and measuring relative irrigation system efficiency. Further investigation is thus required to determine feasibility. Data may be available from provincial government agencies and irrigation districts. Data may also be extracted from case studies.

- It was suggested that provincial agencies be involved in developing the indicator.

**Indicator: Price of Irrigation Water** (Appendix 7.1 -10)

- Price of irrigation water was not seen as a direct indicator of environmental sustainability, but rather as a socio-economic indicator with environmental implications. Participants commented that this indicator may become more of a local or regional issue as competition for water increases. Further, price of irrigation water may be useful for OECD studies and for responding to Agenda 21.

- The data required for developing this indicator are available from irrigation districts and provincial governments. Participants commented on the usefulness of the information this indicator would yield.

**Indicator: Moisture Stress Index** (Appendix 7.1-2)

- The information reported by this indicator was considered useful for signalling water stress during crop growth. This indicator is thus relevant at the management level for planning adaptation strategies such as irrigation scheduling and providing emergency water supplies.

- Data to develop the indicator are available at the provincial level and from Environment Canada, but they need to be standardized.

- As a next step, it was suggested that a pilot study assessment for a particular region be conducted. The study could be used to support long-range planning to respond to irrigation development needs in specific areas. A further suggestion was made to develop regional moisture stress maps.

**Indicator: Percent of Agriculture Land with Sub-Surface Drainage (Appendix 7.1-3)**

- This indicator was not seen as nationally relevant and, like the moisture stress indicator, more useful at a field level for measuring management of and adaptation to water excess.

- It was generally agreed-that this indicator need not be developed.

**Indicator: Percentage of Agricultural Land in Irrigation** (Appendix 7.1-4)

- This indicator was not seen as relevant nationally and, like percent of agricultural land with sub-surface drainage, more useful at a field level for measuring management response and adaptation to water deficits.

- It was generally agreed that this indicator need not be developed, although data are available.

**Indicator: Precipitation** (Appendix 7.1-1)

- Precipitation was seen as highly relevant for managing water supply and for linking to the moisture stress index. Basic information on the supply of water is required to plan adaptation responses to water deficits and surpluses. Participants commented that this indicator would have wider application (e.g. measuring agro-climatic changes).

- Additional parameters were identified to enhance this indicator: snowfall, seasonal influence, and correlating precipitation to a normal/standard value.

- Data to develop this indicator are readily available from Environment Canada and other resource agencies and it is relatively inexpensive to collect. It will be important to coordinate the efforts of all parties during development to avoid duplication of effort.

**Indicator: Available Soil Moisture**
(Appendix 7.1-5)

- This indicator was seen as very useful for providing information at the field level for seeding and at other levels through linkages to issues regarding soil conservation, land use, summer fallow, water use efficiency and cropping patterns. Available soil moisture aids government with policy information regarding crop insurance, the Canada Wheat Board and safety nets. There is also a linkage to the precipitation and moisture stress index indicators.

- The current scale of available information was seen as being too broad for developing this indicator; more field sampling is needed. Concerns surfaced regarding the cost of developing this indicator, and agency coordination will be required to save costs. Data could be collected through remote sensing. The Canada Centre for Remote Sensing is a possible source, but the data may be very expensive.

- Participants suggested co-ordinating data base collection efforts among agencies and encouraging publication of more soil moisture maps.

**Indicator: Groundwater Levels**
(Appendix 7.1-8)

- It was felt that information regarding groundwater levels is highly relevant and will become increasingly important in the future as use of groundwater increases. This indicator is linked to water quality issues, and is useful both for salinity monitoring in Western Canada and for establishing drainage needs in Eastern Canada. There is also a linkage to the sustainable yield index for groundwater.

- Development of this indicator was seen as feasible, but since present data collection efforts are not extensive, areas to be monitored regularly should be carefully targeted. Assessments of shallow aquifers may be less expensive. Since present data collection efforts are not extensive, areas to be monitored regularly should be carefully targeted . Protocols and efforts would have to be standardized and co-ordinated.

- Given concerns about costs and cost effectiveness, it was suggested that any efforts to develop this indicator begin with pilot projects.

**Ranking of Water Quantity Indicators**

- Overall, participants felt that all potential indicators should be retained. However, several participants questioned retaining the price of irrigation of water because it was seen as a policy-derived indicator that encourages efficiency rather than a direct indicator of sustainability.

- Highest ranking was given to the following indicators: precipitation, available soil moisture, sustainable yield indexes for surface water and groundwater, moisture stress index, groundwater levels, and relative irrigated area by system efficiency. There was some discussion on merging the available soil moisture indicator with the precipitation indicator.

- Medium ranking was given to the following indicators: price of irrigation water, percentage of agricultural land with sub-surface drainage and percentage of agricultural land in irrigation,
- Three new areas were identified as important data sources: runoff, reservoir lands, and evaporation.

### RANKING OF WATER QUANTITY INDICATORS

| INDICATOR | RANK |
|---|---|
| Sustainable Yield Index for Surface Water | HIGH |
| Sustainable Yield Index Ground for Water | HIGH |
| Relative Irrigated Area by System Efficiency | HIGH |
| Moisture Stress Index | HIGH |
| Precipitation | HIGH |
| Available Soil Moisture | HIGH |
| Groundwater Levels | HIGH |
| Price of Irrigation Water | MEDIUM |
| % Agricultural Land in Irrigation | MEDIUM |
| % Agricultural Land with Sub-Surface Drainage | MEDIUM |

## 4.3.2: LAND AND SOIL RESOURCES INDICATORS

### Review of Individual Indicators

**Indicator: Land Conversion** (Appendix 7.2-1)

- This indicator was seen as highly relevant, particularly from a regional perspective, in relation to the permanent loss of prime agricultural land.
- The information content as proposed was seen as useful. Participants emphasized the importance of tracking land conversion by land capability class affected. Related parameters could include the price of farmland converted versus the price of non-farmland converted, and the use made of the converted land. The indicator should be sensitive to regional diversity.
- Development is partially feasible, but on a regional basis only because some provinces have begun to collect data on agricultural land conversion (i.e. Alberta, Quebec and British Columbia). At the federal level, comprehensive land conversion data are available up to 1986, although Statistics Canada recently completed a pilot project to assess land use change (land cover, land activity and green space) for the Ottawa-Hull area.
- To pursue this indicator at a national level, it will be necessary to render existing data comparable. It was also suggested that remote sensing be explored as a way of collecting the required data.

**Indicator: Soil Degradation Risk** (Appendix 7.2-2)

- This indicator was seen as relevant and potentially useful as a proxy indicator for more direct measurements of soil quality, which are often difficult and expensive to obtain. However, the use of this indicator to reach definitive conclusions about soil degradation was questioned.

- It was noted that the measurement scale proposed (1:1 million) would not be useful to regional decision-makers. A more sensitive spatial analysis would therefore be required for local needs.

- The feasibility of developing this indicator requires additional investigation because costs may be prohibitive. The Census of Agriculture and existing land vulnerability estimates were cited as useful data sources.

**Indicator: Soil Quality** (Appendix 7.2-3)

- Participants acknowledged the relevance of this indicator to soil resource management but noted difficulties with interpretation, and the choice of soil attributes.

- Participants agreed that, over the longer term, this indicator could be improved through the development of scientific capabilities and possibly through the development of an acceptable soil quality index.

- Current capabilities allow for only a partial development of this indicator for selected parameters. Refinement will depend on the following: advances in scientific understanding, the development of an approach for integrating soil quality attributes into a more composite indicator, and the interpretation of the significance of observed changes.

**Indicator: Crop Yield** (Appendix 7.2-4)

- Many participants felt this was a relevant indicator, but difficult to interpret strictly from a soil quality perspective. Factors other than soil quality (e.g. technological change, market prices and input costs) also influence yield.

- The indicator would be enhanced and rendered more useful if it could be linked more directly to soil quality and other environmental factors.

- Yield data to develop the indicator exist at the provincial level for most crops, and Statistics Canada also has a time series of this information. What will be required is a capability to determine yield variability on the basis of factors which influence it; tools such as the Erosion Productivity Impact Calculator (EPIC) model may be useful.

**Indicator: Soil Cover/Management**
(Appendix 7.2-5)

- Participants felt this was a good and very useful indicator because it is simple, understandable and relevant to the farm community. It would also help track and evaluate the effectiveness of efforts to encourage sustainable soil management.

- The feasibility of developing this indicator is good because data are available from the Census of Agriculture, the Prairie Farm Rehabilitation Administration, the provinces, and various individual studies. The importance of including crop rotation as a parameter in the indicator was emphasized, as was the use of remote sensing as a tool for obtaining relevant data.

- Participants agreed that the soil cover/management indicator should be identified as a priority for development.

**Indicator: Adoption of Soil Conservation Practices** (Appendix 7.2-6)

- Participants agreed that this could be a useful indicator of land conservation and stewardship, but that it will be necessary to obtain agreement on what constitutes a sustainable soil conservation practice; it could be interpreted by different people to mean different things.

- The utility of the indicator could be enhanced if broad agreement were obtained on a suitable set of practices to be reported by the indicator.

- Data on certain soil conservation practises at the farm level are available from Statistics Canada and other sources. Participants recommended continuing with efforts to collect relevant data through the Census of Agriculture, while making careful use of data already available.

**Indicator: Nutrient Balance** (also discussed by the Agriculture Inputs Group - Appendix 7.2-7)

- Nutrient balance was seen as being relevant to both the soil quality and water quality issues. Participants felt this indicator was also easily understood and thus important to develop from a policy perspective.

- Participants felt the indicator would be most useful if developed at the farm scale and then reported at whatever scale (e.g. watershed or land resource area) is appropriate to the specific needs of future users.

- Development was seen as feasible in the medium term. Although estimates of nutrient inflows and outflows can be generated, the effectiveness of the indicator would be improved considerably if detailed data on fertilizer use were available. Development of this indicator should continue, including efforts to obtain more detailed and reliable data on fertilizer use.

**Indicator: Soil Contamination** (Appendix 7.2-8)

- There was considerable debate about the policy relevance of soil contamination. Those that supported the indicator argued that soil contamination is especially important in areas of intensive production such as Manitoba, Ontario and Quebec. Soil contamination is also important given the increasing use of agricultural land for urban/industrial waste disposal (e.g. municipal sludge). Participants opposing this indicator asserted that this is an important issue internationally but not within Canada.

- The data required to develop this indicator are not presently available and would be costly to obtain. No specific additional steps were identified for this indicator.

**Ranking of Agricultural Land and Soil Indicators**

- Participants agreed that all indicators should be retained, but that crop yield should be incorporated or linked with other indicators or issues because it is difficult to interpret on its own strictly from a soil quality perspective. Participants also suggested that the soil quality and soil bio-quality/health indicators be merged into one indicator.

- The indicators that received highest ranking were land conversion, soil cover/ management, adoption of soil conservation practices, and nutrient balance.

- Medium-ranked indicators include soil contamination, soil degradation risk, soil quality, and crop yield.

**RANKING OF LAND AND SOIL RESOURCES INDICATORS**

| INDICATOR | RANK |
|---|---|
| Land Conversion | HIGH |
| Soil Cover/Management | HIGH |
| Adoption of Soil Conservation Practices | HIGH |
| Nutrient Balance | HIGH |
| Soil Contamination | MEDIUM |
| Soil Degradation Risk | MEDIUM |
| Soil Quality (including Soil Bio-Quality/Health) | MEDIUM |
| Crop Yield | MEDIUM |

### 4.3.3: GENETIC DIVERSITY INDICATORS

#### Review of Individual Indicators

In addition to recommending in Task One that the genetic diversity and wildlife habitat issues be merged, participants also suggested combining several other individual indicators.

**Indicator: Crop and Livestock Production Diversity, and Crop and Livestock Genetic Diversity** (Appendices 7.3-1, 7.3-2)

- Both of the above indicators were considered relevant, but it was suggested that they be combined into a single indicator of **genetic utilization** (of species used in agricultural production). This was seen as relevant to the requirements of the Biodiversity Convention that call for domestic (and wild) species to be conserved. Participants provided the rationale that genetic material not in use is at risk of eventually being lost.

- To develop a meaningful genetic utilization indicator, it was suggested that all relevant information on extent of use of genetic material be identified and organized. A simple count of cultivars and breeds contributing to output is not by itself a reliable indicator of genetic diversity. Use of a large number of varieties does not guarantee diverse germ plasm and could be a misleading approach.

- Some data to develop a genetic utilization indicator are available, through breed associations, private industries, and the Census of Agriculture.

- Participants suggested proceeding with development of this indicator. It was also suggested that standards be established to help determine how much diversity is "enough".

**Indicator: Crop and Livestock Genetic Preservation** (Appendix 7.3-3)

- Participants felt this is a relevant indicator which could also deal with the important issue of access to genetic material. However, much of the genetic material used in Canadian agriculture originates elsewhere and is stored elsewhere, thus making it difficult to collect and control.

- Information on genetic material stored in Canada is available for both animals and plants. However, participants suggested a global approach for this indicator, pointing out that it would perhaps best be developed by an international agency or group of agencies.

**Indicator: Soil Bio-Quality/Health and Water Bio-Quality/Health**
(Appendices 7.3-4, 7.3-5)

- These indicators were seen as potentially relevant, but it was recognized that considerable conceptual and technical work will be required to develop a means of measuring changes in biodiversity within agroecosystems i.e. agroeco-system biodiversity indicator. It will also be important to develop interpretation criteria for determining the significance of observed changes.

- Some data relating to each of the two indicators are available. In some cases it may be necessary to establish linkages with other biological indicators of soil and water quality.

**Indicator: Biocontrol** (Appendix 7.3-6)

- Participants agreed that this is not a relevant biodiversity indicator, and that is more directly related to the agricultural input issue. The possibility of including it as part of the composite pesticide management indicator was identified.

**Indicator: Beneficial Species**
(Appendix 7.3-7)

- It was suggested that this indicator become part of the wildlife population indicator since it was not considered directly related to the genetic diversity issue.

- Data may be available from Agriculture Canada, Environment Canada, Natural Resources Canada (Forestry), the Canadian Museum of Nature, and perhaps other federal, provincial and private sector agencies. Once all data have been collected, it was suggested that a database be established and a standard determined for all species considered to be "at risk".

**Indicator: Non-Crop Soil Cover**
(Appendix 7.3-8)

- Participants felt that this is a relevant indicator that could perhaps be included as part of habitat availability since both soil and inherently all soil cover are habitats.

- Little information was available regarding data sources thus a feasibility study was suggested prior to any further work being undertaken to develop this indicator.

**Ranking of Genetic Diversity Indicators**

- For genetic diversity of species used in agricultural production, participants ranked the proposed genetic utilization indicator high in priority. The crop and livestock genetic preservation index was seen as important, but assigned a medium priority since it may be more appropriate on an international scale.

- Participants felt that an indicator (1 measuring biodiversity in agroecosystems was also required and placed a high priority on developing such an indicator, which could include elements of the soil bio-quality and water bio-quality indicators.

- The biocontrol, beneficial species and non-crop soil cover indicators were not ranked. It was suggested that they be merged with other indicators and were thus seen as relevant from that perspective. For example, the biocontrol index, beneficial species and the non-crop soil cover indicators are linked with, respectively, the inputs issue, the wildlife population indicator and the habitat availability indicator.

- Agro-ecosystem biodiversity could incorporate elements of the soil bio-quality and water bio-quality indicators.

**RANKING OF GENETIC DIVERSITY INDICATORS**

| INDICATOR | RANK |
|---|---|
| Genetic Utilization | HIGH |
| Agro-ecosystem Biodiversity | HIGH |
| Crop & Livestock Genetic Preservation | MEDIUM |
| Biocontrol | N/R |
| Beneficial Species Indicator | N/R |
| Non-Crop Soil Cover | N/R |

* N/R = not ranked

### 4.3.4: WILDLIFE HABITAT INDICATORS

**Review of Individual Indicators**

**Indicator: Habitat Availability** (Appendix 7.4-1)

- This indicator was perceived to be highly relevant because it is directly linked to on-farm land use and cover.
- The indicator could be improved by harmonizing or standardizing habitat classification systems used in Canada. Considerable variation exists in wildlife habitat definitions and classifications. Participants also suggested linking habitat fragmentation with habitat availability.
- Land cover types were seen as important indicators of habitat availability. It was thus seen as essential that distinctions between cover types be made as they may have different values for different species.
- Suggestions for proceeding with this indicator included:
  - establishing a national ecological classification system based on cover type;
  - improving the comprehensiveness of the data on land cover and use gathered at the farm level through the Census of Agriculture;
  - using remote sensing to collect needed data;
  - collecting data through municipal and provincial tax records;
  - doing a cost/benefit assessment of using farm level data versus remote sensing data;
  - reporting the indicator on a five-year cycle.

**Indicator: Habitat Quality** (Appendix 7.4-2)

- This indicator was considered relevant since habitat quality can be affected by agriculture and impact on wildlife residing in agricultural landscapes.
- Key parameters of habitat quality need to be defined e.g. type of contamination, degree of degradation, number of obstructions such as roads, fences and powerlines. The development of appropriate standards or criteria for assessing habitat quality was also seen as important.
- Some habitat quality data are available at the provincial level, but many gaps exist. It may be possible to enlist the cooperation of volunteers and landowners in collecting relevant information (e.g. the spread of exotic species).
- No specific recommendations emerged regarding next steps in the development of this indicator.

**Indicator: Habitat Fragmentation**
(Appendix 7.4-3)

- This indicator was seen as very important because it is a critical factor affecting the availability and quality of habitat for wildlife.

- Development of the indicator is questionable at present because fragmentation and critical habitat size requirements of wildlife species are poorly understood. As knowledge of fragmentation is still rudimentary, reliable data are scarce. Suggestions for collecting data included regional remote sensing and consultation of municipal maps.

- Development of this indicator can only progress as understanding improves and information becomes available. It may be useful to combine information from the habitat fragmentation and the habitat availability indicators.

**Indicator: Habitat Restoration**
(Appendix 7.4-4)

- This indicator was seen as a relevant indicator of society's response to the habitat loss issue.

- Participants felt that it could be included or combined with the habitat availability indicator to avoid double counting.

**Indicator: Wildlife Species at Risk**
(Appendix 7.4-5)

- This indicator was perceived as relevant but somewhat limited on its own because it covers a very small range of species (i.e. vertebrates).

- Information is readily available from the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

- Participants felt that the wildlife species at risk indicator could be merged with the wildlife population indicator.

**Indicator: Wildlife Population**
(Appendix 7.4-6)

- This indicator has important policy relevance because it provides a measure of the stability of wildlife abundance and diversity. However, the relevance of this indicator to agriculture is indirect since factors external to agriculture also affect wildlife populations.

- It would be helpful to distinguish between resident and non-migrant species when estimating trends in wildlife populations.

- Elements of this indicator are already being pursued by other agencies such as Environment Canada. Participants felt that the habitat availability indicator provides a better measure agriculture's relationship with wildlife than the wildlife population indicator.

**Ranking of Wildlife Habitat Indicators**

- The wildlife habitat group ranked habitat availability, quality and fragmentation as the highest priority indicators because of their direct linkage to habitat and land use in agricultural landscapes. As populations of many species are affected by factors external to agriculture, the wildlife population indicator was assigned a medium priority for agriculture. It was suggested that habitat fragmentation be merged with habitat availability.

- The habitat restoration and wildlife species at risk indicators were not ranked. It was suggested that these could be integrated with, respectively, the habitat availability and wildlife population indicators.

**RANKING OF WILDLIFE HABITAT INDICATORS**

| INDICATOR | RANK |
|---|---|
| Habitat Availability & Fragmentation | HIGH |
| Habitat Quality | HIGH |
| Wildlife Population | MEDIUM |
| Habitat Restoration | N/R |
| Wildlife Species at Risk | N/R |

* N/R = not ranked

### 4.3.5: AIR & CLIMATE INDICATORS

**Review of Individual Indicators**

**Indicator: Agricultural Greenhouse Gas Balance**

- Participants suggested combining the four potential indicators dealing with greenhouse gas emissions (listed below) into an overall greenhouse gas balance for the agricultural sector. Greenhouse gas emissions from energy use would also be included in a greenhouse gas balance.
  - **Crop Production Carbon Balance** (Appendix 7.5-1)
  - **Methane Emissions from Domestic Ruminants** (Appendix 7.5-2)
  - **Greenhouse Gas Emissions from Animal Wastes** (Appendix 7.5-4)
  - **Relative Use of Nitrous-oxide-emitting fertilizers** (Appendix 7.5-3)
- It was agreed that the individual components of agricultural greenhouse gas emissions are much more relevant in combination with one another, and corrected for carbon sequestering rather than as individual emissions indicators. A greenhouse gas balance would be relevant to Canada's reporting commitments for the Climate Change Convention. It could support policy design aimed at maximizing the agricultural sector's contribution to the sequestering of carbon as a strategy for reducing the risks of climate change. This indicator will be very relevant if a carbon tax comes into effect.
- The feasibility of developing this indicator was not discussed in detail, but considerable scientific work will be required to develop a comprehensive and credible greenhouse gas balance. It was recognized that approaches to converting various greenhouse gases into $CO_2$ equivalents have been developed and used elsewhere.
- It was suggested that work to develop this indicator be pursued in collaboration with other agencies pursuing similar work, notably Natural Resources Canada and Environment Canada.

**Indicator: Changes in the Agricultural Climate** (Appendix 7.5-5)

- This indicator was seen as relevant to the development of policy responses to environmental changes which may affect agriculture.
- Data required for this indicator are available from Environment Canada and Agriculture Canada (daily meteorological data). Indices will need to be computed to match the scale of reporting required. This will involve costs. If suitable, the results from existing studies should be considered for use.

- Participants suggested moving toward immediate reporting of data, updating climate assessment for agriculture, tracking long-term climate changes and their impacts, monitoring climate variability and occurrence of extreme events, and using climate models in agricultural management decisions.

**Indicator: Crop Water Use Efficiency** (Appendix 7.5-6)

- Participants saw this as a very specific indicator that has no direct policy relevance on its own. It was therefore suggested that it be incorporated into the Greenhouse Gas Balance.

- It was pointed out that increased levels of carbon dioxide can improve water use efficiency and crop photosynthesis rates, thus possibly offsetting some of the negative impacts of climate change on agriculture. Used in another context, this indicator could provide a measure of climate change and how it may be affecting crop yield.

- To develop this indicator, information regarding water use efficiency can be easily extrapolated across Canada through field research. It was suggested that a feasibility study be undertaken on producing an indicator which separates out the effects of $CO_2$ on water use efficiency from other contributing factors.

**Ranking of Air & Climate Indicators**

- The agricultural greenhouse gas balance and agricultural climate indicators were ranked highest in priority. It was suggested that precipitation could be included in the changes in agriculture climate indicator and that crop water use efficiency could be merged with greenhouse gas balance.

- Three new indicator areas were suggested: ground-level ozone pollution, stratospheric ozone depletion and land use impacts on air quality. However, these were seen as secondary in priority. For simplicity, they could be grouped together solely on the basis of crop damage.

**RANKING OF AIR & CLIMATE INDICATORS**

| INDICATOR | RANK |
|---|---|
| Agricultural Greenhouse Gas Balance* | HIGH |
| Changes in the Agricultural Climate | HIGH |
| Crop Water Use Efficiency | LOW |
| Precipitation | LOW |

* Agricultural Greenhouse Gas (GHG) Balance is a result of merging crop production carbon balance, methane emissions from domestic ruminants, greenhouse gas emissions from animal wastes and relative use of nitrous-oxide-emitting commercial fertilizers.

### 4.3.6 AGRICULTURE INPUTS INDICATORS

Potential indicators related to agricultural inputs were discussed in three areas: nutrients, pesticides and energy.

**Review of Nutrient Input Indicators**

**Indicator: Fertilizer Use Intensity**
(Appendix 7.6-4)

- The relevance of fertilizer use intensity was questioned by some participants, who saw it more as a data set than an indicator. Others felt it could be useful and relevant if expressed as a ratio of fertilizer use relative to productivity rather than as applications per unit area of land. This indicator is beneficial in allowing for international comparisons. It is currently being reported by the OECD (as Tonnes Nitrogen applied/$km^2$ ).

- This indicator would benefit from a distinction between chemical and manure fertilizers.

- Feasibility was questioned because detailed data on fertilizer applications by crop may be difficult to obtain. Aggregate data on applications by crop and per area of land are available from the FAO and OECD respectively.

**Indicator: Nutrient Balance** (also discussed by the Land & Soil Group, Appendix 7.2-7)

- Participants felt that this indicator has important policy relevance because it links to both soil and water quality issues and provides an important measure of sustainable nutrient input use.

- The possibility of linking this indicator with fertilizer use intensity was suggested. It was agreed that the indicator would be more useful if calculated at a regional rather than national level.

- The feasibility of developing this indicator was identified as a concern since detailed data may be difficult to obtain, but participants felt this indicator should definitely be pursued.

**Ranking of Nutrient Input Indicators**

- Of the initial indicators identified, nutrient balance was ranked as the most important, followed by fertilizer use intensity and plant nutrient contamination (of water). For plant nutrient contamination of water, it was suggested that the source of contamination be identified to make it more meaningful. This recommendation is consistent with the discussions of the water quality focus group.

- Of the two options for reporting fertilizer use intensity (kg/ha or kg/per unit of production), the latter approach was favoured.

- It was suggested that a nutrient management indicator be included to identify current approaches and practices associated with fertilizer use. This new indicator was ranked high in priority.

**RANKING OF NUTRIENT INPUT INDICATORS**

| INDICATOR | RANK |
|---|---|
| Nutrient Balance | HIGH |
| Nutrient Management | HIGH |
| Fertilizer Use Intensity | MEDIUM |
| Plant Nutrient Contamination (of water) | MEDIUM |

**Review of Pesticide Input Indicators**

**Indicator: Composite Pesticide Management** (Appendix 7.6-5)

- This indicator was seen as being very relevant as it provides a measure of how pest control products are being managed/used from an environmental perspective (i.e. best management practices for pesticides).

- The indicator could be improved by developing agreement on best management practices for pesticides and defining pest management approaches (e.g. Integrated Pest Management) more precisely. Information about actions by governments and industry to promote sound management of pesticides would enhance the relevance of the indicator.

- Participants felt that this indicator could be developed, at least for certain practices. Currently, some relevant information and data are likely available from the provinces, from industry, and possibly, over the longer term, from the Census of Agriculture.

**Indicator: Composite Pesticide Risk**
(Appendix 7.6-7)

- Two views about the relevance of this indicator were expressed: some participants saw it as being highly relevant and thus very important to track over time, while others felt it is not relevant on its own, but could be used in relation with the pesticide management indicator.

- To develop the indicator, an environmental risk classification system will be required. This was identified as a first step. Data on pesticide use are presently available at the national and provincial levels. Detailed data are available but confidential.

**Indicator: Composite Pesticide Use**
(Appendix 7.6-6)

- Participants agreed that, on its own, pesticide use (where all pesticides are lumped together) is not relevant or meaningful from an environmental perspective.

- This indicator was seen more as a data set which would be required to develop the pesticide risk indicator. Data on pesticide use would be enhanced with detailed information on the number of applications per year, on applications by crop in specific areas, etc.

- Usage of pesticide use data as a stand-alone indicator was generally not recommended.

**Ranking of Pesticide Input Indicators**

- There was general agreement that the composite pesticide management indicator be ranked high in priority. Some participants felt the pesticide risk indicator should also be assigned a high priority, while others disagreed. It has therefore been assigned a medium ranking.

- It was also suggested that, over the longer term, a single agri-environmental indicator be developed for pesticides to account for use, management practices and environmental effects. There is potential for linking some of these indicators, particularly pesticide management and pesticide risk, with the pesticide risk reduction strategy being considered in Canada and internationally.

- One new indicator was introduced: pesticide use intensity (use per unit of output). These types of production efficiency indicators (ratio of input per unit of output) were seen to be valuable for both pesticide input and nutrient input.

**RANKING OF PESTICIDE INPUT INDICATORS**

| INDICATOR | RANK |
|---|---|
| Composite Pesticide Management | HIGH |
| Pesticide Use Intensity | MEDIUM |
| Composite Pesticide Risk | MEDIUM |
| Composite Pesticide Use | LOW |

**Energy Input Indicators**

**Review of Individual Indicators**

Indicator: Quantities of fuel use (by type) for field operations per cultivated area, per quantity of output and value of production by province (Appendix 7.6-1)

- Participants agreed that agricultural fuel use per unit of output was a relevant indicator.

- The feasibility of developing this indicator is likely low because detailed data on farm energy use are not current in Canada, except at a highly aggregated level. The importance of tracking energy use by type or source (e.g. renewable & non-renewable) was emphasized.

**Indicators: Energy consumption by livestock under confinement per unit of output & value of production, by province, (Appendix 7.6-2) and**

**Quantity of energy used on-farm not related to field operations or confined livestock.** (Appendix 7.6-3)

- These indicators were not discussed in detail. Participants suggested that, ideally, an energy input-output balance would be developed as a measure of energy use efficiency relative to productivity.

**Ranking of Energy Input Indicators**

- Of the three potential indicators, it was suggested that only one be retained: quantity of fuel use (by type) for field operations per cultivated area, per quantity of output and value of production, by province. This indicator was ranked the best of all three because it can provide a measure of production efficiency and is thus consistent with the proposed fertilizer and pesticide use intensity indicators.

- The indicators energy consumption by livestock under confinement per unit of output and value of production, by province and quantity of energy used on-farm not related to field operation or confined stock were considered less relevant.

- Participants felt that the indicators did not capture the full energy cycle and that, ideally, a more comprehensive farm energy input-output indicator should be considered.

**RANKING OF ENERGY INPUT INDICATORS**

| INDICATOR | RANK |
|---|---|
| Quantity of fuel use (by type) for field operations per cultivated area, per quantity of output and value of production, by province | HIGH |
| Energy Input-output Balance | HIGH |
| Energy consumption by livestock under confinement per unit of output & value of production, by province | N/R |
| Quantity of energy used related to field operations or confined livestock | N/R |

### 4.3.7 SURFACE AND GROUNDWATER QUALITY INDICATORS

**Review of Individual Indicators**

**Indicator: Pesticide Contamination (of water)** (Appendix 7.7-1)

- Participants felt this indicator was highly relevant and provided a good basic measure of the quality of water resources. It addresses a key concern about pesticide use in agriculture (water contamination & excessive or improper pesticide use) and provides a good signal of sustainability (or unsustainability), which should trigger a policy response.

- Participants emphasized the importance of ensuring proper interpretation of the indicator and measuring pesticide contamination in other media such as aquatic life. Pesticides with short half lives may not be detected in water because of the time window for sampling and also because some compounds bioaccumulate or are stored in sediments. Their presence in an aquatic ecosystem, even for a few hours, could do significant damage to the food chain.

- The development of this indicator will take time because water quality data are not comprehensive and are held by various federal and provincial agencies. Participants suggested that, as a first step, an adequate baseline of information be established for each region, as well as sampling protocols and requirements. It was suggested that continuous spot monitoring may be adequate as opposed to regular intensive monitoring. Inter-agency collaboration was seen as essential for developing this indicator.

- Since numerous pesticides are being used, it will be necessary to prioritize which ones can be used as "benchmark" indicators. Hence, an inventory of pesticides and current monitoring will be required. The pesticide indicators that are selected should represent a broad range of pesticides. It was recommended that a 5-to 10-year reporting scale be used.

**Indicator: Plant Nutrient Contamination (of water)** (Appendix 7.7-2)

- Participants felt this indicator was highly relevant because it provided a good basic measure of the quality of water resources. It addresses a key concern about input use (fertilizers, manure) in agriculture (water contamination & excess or improper input use). It is also closely linked to land issues and management practices, and provides a good signal of sustainability (or unsustainability), which should trigger a policy response.

- It was suggested that nutrient contamination be measured separately in groundwater and in surface water. The indicator would be improved by linking water contamination to soil nutrient content, land management, and input use.

- Existing sampling protocols and analytical capabilities are well developed, and data on nutrient levels in water exist for some water bodies. A key challenge to be addressed, however, is interpretation of the indicator from an agricultural perspective, considering that many other sectors, activities and natural processes within agro-ecosystems also contribute or influence nutrients loadings (nitrogen and phosphorus) to aquatic ecosystems.

**Indicator: Agricultural By-Products (concentrations in water)**
(Appendix 7.7-3)

- Participants agreed that this indicator is very relevant to the development of policies related to agricultural management and environmental concerns. As with the other water quality indicators, it provides a basic measure of the quality of water resource.

- It was suggested that by-products from other industries (e.g. forestry, fisheries and municipal wastes) be included. To further enrich this indicator and improve its use as a management tool, it could be seasonally adjusted to climate so that it reflects expected leaching or runoff.

- Information to develop the indicator is not readily available, and interpretation from an agricultural perspective poses problems because many other sectors and activities contribute by-products. Various processes in agro-ecosystems also influence movement of by-products into water (e.g. soil cover). Overall, this is a complex indicator and it is important that it be sensitive to regional conditions.

**Indicator: Solids Loading Indicator (concentrations in water)** (Appendix 7.7-4)

- This indicator was seen as relevant because concentrations of solids in water are related to processes such as soil erosion and land management. Sedimentation is a major concern regarding surface water quality and a vehicle for pesticides and nutrients to move off the field into water bodies.

- The indicator could be improved by focusing on sedimentation and impacts related to fish (aquatic) habitat.

- Data for some watersheds are available from Environment Canada and the provinces. However, there may be difficulties in establishing linkages between observed concentrations of sediment in water and agricultural sources because other factors and processes also contribute to the problem. A strong linkage to agricultural management practices was recommended.

**Ranking of Surface & Groundwater Quality Indicators**

- In addition to the indicators which directly measure water quality, participants also considered indicators from other issues (particularly from inputs and soil resources) that relate to water quality management. These are included in the table below.

- Participants felt that for an indicator to be relevant, it must show a link between the cause (agriculture) and the effect (water quality). Given this approach, it was felt that the existing indicators were not sufficiently predictive and that over the long term, indicators should be linked or perhaps even combined in a manner which demonstrates cause and effect linkages. For example, the fertilizer use intensity indicator could be better utilized if it were merged with the plant nutrient contamination indicator.

- The indicators which directly measure the condition of the resource were ranked highest: pesticide contamination, plant nutrient contamination, agricultural by-products and soils loading. It was felt these are the core indicators for monitoring and measuring water quality over time.

**RANKING OF SURFACE & GROUNDWATER QUALITY INDICATORS**

| INDICATOR | RANK |
|---|---|
| Pesticide Contamination | HIGH |
| Plant Nutrient Contamination | HIGH |
| Agricultural By-Products | HIGH |
| Solids Loading | HIGH |
| Fertilizer Use Intensity | MEDIUM |
| Soil Contamination | MEDIUM |
| Soil/Cover Management | MEDIUM |
| Adoption of Soil Conservation Practices | MEDIUM |
| Composite Pesticide Risk | MEDIUM |
| Composite Pesticide Management | MEDIUM |
| % Agricultural Land with Sub-Surface Drainage | MEDIUM |
| Habitat Quality | N/R |
| Nutrient Balance | N/R |
| Water Quality/Bio-Health | N/R |

* N\R = not ranked

- A medium ranking was assigned to indicators which measure practices that may affect the quality of water: fertilizer use intensity, soil contamination, soil cover/ management, adoption of soil conservation practices, composite pesticide risk, composite pesticide management and percentage of agricultural land with sub-surface drainage. These were seen as important but perhaps better utilized if merged with other issues.

- The following indicators were not explicitly ranked: water quality bio-health indicator, habitat quality indicator and nutrient balance indicator.

**4.4 TASK FIVE: next steps to be pursued in the agri-environmental indicator development project.**

Participants were asked for suggestions in three main areas: next steps in the project, potential partnerships for developing the indicators, and possible options for reporting the results of the project.

**RESULTS**

**Next Steps**

- Participants made two main recommendations

  1) preparing an overall strategic plan for the indicator project that would identify a set of priority or core indicators for development, and

  2) preparing a specific work plan for each priority indicator.

- The strategic plan could

  - specify long-term objectives for the project;
  - determine a consultation process;
  - identify priority indicators, results and timeliness;
  - identify partners.

- A work plan for each priority indicator could identify timeliness, resources, expected results, and who will be involved in developing the indicator.

- Other suggested next steps included:

  - testing the priority indicators against criteria such as statistical reliability and relevance to decision makers;

  - assessing information sources and gaps;

  - clarifying long-term goals and targets for agri-environmental sustainability;

  - conducting feasibility studies of priority indicators as required.

**Partnerships**

- Participants felt that partnerships are essential to the development ofindicators. Suggestions included looking closely at the work being done in the United States and, on a national scale, involving provinces, other federal departments, producers, financial institutions, universities, environmental groups, and commodity groups as appropriate. Universities could provide both information and expertise.

- It was highly recommended that consultations with stakeholders and partners continue throughout the project.

- Other potential mechanisms for partnerships included

  - formal agreements with the provinces and other federal departments (e.g. Environment Canada) on indicator development;

  - working with the Federal-Provincial Accord Committees on Environmental Sustainability from each province;

  - ensuring that the work is linked to other relevant initiatives, such as Canadian implementation of the Biodiversity and Climate Change conventions;

- establishing multi-stakeholder teams to develop specific indicators as needed.

**Reporting Options**

- Participants discussed and identified several options for reporting project results. A variety of mechanisms were seen as having potential value for disseminating information (e.g. local radio, print media, computer networks, conferences, and demonstration sites).

- Specific options included

  - periodic "state of agriculture" reports;

  - periodic agri-environmental indicator bulletins or fact sheets;

  - indicator reports to the annual meetings of federal and provincial Ministers of Agriculture.

- Participants felt that regardless of the reporting options used to disseminate information, indicators should only be reported once their rigour and relevance has been firmly established.

- Participants emphasized that the indicators should be reported in a manner useful to the farmers for assessing progress towards environmental sustainability.

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Consultation Workshop on Agri-Environmental Indicators - Final Report

# 6.0 ATTACHMENTS

## 6.1 WORKSHOP PROGRAM

***MONDAY, 6 DECEMBER 1993***

| | |
|---|---|
| **8:30 - 8:45** | *Opening Remarks - C. Nymark, Agriculture & Agri-food Canada , AAFC* |
| **8:45 - 9:05** | *Federal Perspective on Environmental Indicator Development - A. Kerr, Environment Canada* |
| **9:05 - 9:25** | *Overview of Agri-environmental Indicator Project - T. McRae, AAFC* |
| **9:25 - 9:40** | *Presentation on Water Quality Indicators - D. Bielby, AAFC* |
| **9:40 - 9:55** | *Presentation on Agricultural Land & Soil Indicators - J. Culley, AAFC.* |
| **9:55 - 10:10** | *Presentation on Agricultural Inputs Indicators - D. Culver, AAFC.* |
| **10:10 - 10:30** | *Question period* |
| **10:30 - 10:45** | *Coffee* |
| **10:45 - 11:00** | *Presentation on Air & Climate Indicators - J. Dyer, AAFC.* |
| **11:00 - 11:15** | *Presentation on Genetic Diversity Indicators - P. Marriage, AAFC.* |
| **11:15 - 11:30** | *Presentation on Water Quantity Indicators - R. Lien, AAFC.* |
| **11:30 - 11:45** | *Presentation on Wildlife Habitat Indicators - T. Weins, AAFC.* |
| **11:45 - 12:15** | *Question Period* |
| **12:15 - 1:30** | *Lunch and Presentation on Environmental Indicator Research at the OECD K. Parris, Organization for Economic Co-operation & Development* |
| **1:30 - 1:45** | *Instructions to Breakout Groups - E. Gordon* |
| **1:45 - 3:00** | *Breakout Group Session 1* |
| **3:00 - 3:15** | *Coffee* |
| **3:15 - 4:45** | *Breakout Group Session 1* |
| **4:45 - 5:30** | *Breakout Group reports (plenary)* - rapporteurs . |
| **5:30 - 7:30** | *Reception* |

***TUESDAY, 7 DECEMBER 1993***

| | |
|---|---|
| ***8:30 - 8:40*** | *Anticipated Outcomes for Day 2 - C. Nymark* |
| **8:40 - 8:50** | *Instructions to Breakout Groups - E. Gordon* |
| **8:50 - 10:30** | *Breakout Group Session No. 2.* |
| **10:30 - 10:45** | *Coffee* |
| **10:45 - 12:00** | *Breakout Group Session 2 (continued)* |
| **12:00 - 1:00** | *Lunch and Presentation on Indicators as Tools for Achieving Environmental Sustainability - A. Lazar, AAFC* |
| **1:00 - 2:30** | *Breakout Group Session 3* |
| **2:30 - 2:45** | *Coffee* |
| **2:45 - 3:45** | *Breakout Group reports (plenary) - rapporteurs, discussion.* |
| **3:45 - 4:00** | *Concluding remarks - C. Nymark* |

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## 7.0 ENVIRONMENTAL INDICATORS DISCUSSED AT THE WORKSHOP

7. Section 7 is included for reference purposes. The descriptions of the potential indicators were prepared by the committees which developed the issue papers for the workshop.

7.1 Potential Water Quantity Indicators

7.2 Potential Agricultural Land & Soil Indicators

7.3 Potential Genetic Diversity Indicators

7.4 Potential Wildlife Habitat Indicators

7.5 Potential Air and Climate Indicators

7.6 Potential Agricultural Inputs Indicators

7.7 Potential Water Quality Indicators

## APPENDICES OF POTENTIAL WATER QUANTITY INDICATORS

1 Precipitation
2 Moisture Stress Index
3 Percent of Agricultural Land With Subsurface Drainage
4 Percent of Agricultural Land in Irrigation
5 Available Soil Moisture
6 Sustainable Yield Index - Surface Water
7 Sustainable Yield Index - Groundwater
8 Groundwater Levels
9 Relative Irrigated Area by System Efficiency
10 Cost of Irrigation Water

## APPENDIX 7.1-1: PRECIPITATION

**INDICATOR:** Precipitation expressed in absolute terms, as a percentage of normal, and as a five year moving mean on a full period of record trend line.

**RATIONALE AND POLICY RELEVANCE:** The recycling and supply of fresh water is easily and effectively measured temporally and spatially by precipitation. The timing, volume, rate and state (solid or liquid etc.) determines the path taken through the hydrological cycle. Ultimately the ability to supply water for drinking and cleaning, plant and animal growth and development depends on precipitation. The entire history of development is closely related to the availability of precipitation, which defines the practical limits of crop production, livestock, wildlife and human population densities.

To measure the sustainability of agriculture and rural society using precipitation a long term trend analysis of is necessary. In order to monitor the seasonal and annual variations absolute values and percent of the long term record are recommended.

**REPORTED PARAMETERS:** Parameters to be used are:

1) Total precipitation (mm)
2) Percent of Normal Precipitation (full period of record)
3) Five year running mean expressed graphically on a time series of five year running means for the full period available at each weather station. Limits must be defined for the sustainability of the current system for each region represented by the station.

**SPATIAL SCALE:** The data should be collected on the basis of land-based regions such as the Land Resource Region (LRR) proposed for the Prairie provinces by Dumanski et al, at the Centre for Land and Biological Resources Research (CLBRR), at Ottawa.

**TEMPORAL SCALE:** The time scales that are to be reported on depend on the application. For agriculture the period September 1 to September 1, correlates best with the water demands. Total and percent of normal measurements for the year could be measured for this period. Seasonal breakdowns appropriate for surface and ground water supply, annual and perennial crop water supply should be used.

A five year moving mean of the annual September 1 to September 1, precipitation would provide an indicator for long term sustainability measurements. Five year moving averages are proposed since five year aggregates eliminate some of the year to year variability but do not coincide with any known periodic driving forces such as lunar, solar and ENSO cycles. Since it is proposed to evaluate the state of all indicators every five years the five year mean seems appropriate.

**OPTIONS FOR DIS-AGGREGATION:** Precipitation as an indicator for measuring long term change or short term variation may defined by several temporal variations to be more specific to the type of water supply being assessed. Likewise, differences in the lengths of seasons make it appropriate to fine tune the indicators temporal characteristics to the nature of the seasons.

**LINKAGE WITH OTHER ISSUES:** Precipitation will link to virtually all of the other indicators. Its vast significance spans for example, from defining the limits of agriculture to helping to purifying the air.

**DATA SOURCES:** Environment Canada is responsible for collecting and maintaining the climate data archive which will provide most of the required data for this indicator. For the purpose of long term climate change AES is defining Climate Reference Stations, which should form a basis for this indicator. Likewise the Agriculture Canada Weather Stations provide quality controlled reliable data that should be an integral part of this proposed Climate Reference Station list.

**NATURE AND EXTENT OF INTERPRETATION:** This indicator can be easily interpreted and easily understood by users and is applicable across Canada. As long as due consideration is given to the temporal and spatial characteristics of precipitation relative to the regional demands this indicator can be very representative and specific.

**FEASIBILITY FOR DEVELOPMENT AND NEXT STEP:** The indicator is being used throughout the country in different forms. Because the LRRs are already defined for the Prairies the indicators can be fully in place within a year. To apply the same concept across Canada may require a few years of work (check with CLBRR to determine status of this work.)

## APPENDIX 7.1-2: MOISTURE STRESS INDEX

**INDICATOR:** In order to measure stress in the water supply system a moisture stress indicator is proposed for plants and a net evaporation indicator is proposed for open water bodies.

**RATIONALE AND POLICY RELEVANCE:** A knowledge of evaporation and evapotranspiration is particularly useful in agriculture, hydrology, wildlife habitat preservation, and the design and operation of reservoirs, effluent ponds, irrigation and drainage systems. Climatic variability and change may impact on the evapotranspiration demands of agricultural crops and impact on the availability of water through changes in the net evaporation.

The moisture stress indicator for plants is the accumulated daily shortfall between the plant water supply and demand. This accumulated stress value can be used to illustrate seasonal stresses and long term trends. This data may be used for identifying the demand on drought programs such as crop insurance or the sustainability of the cropping systems.

In semi-arid regions such as the Prairies evaporation from open water bodies makes up a significant amount of the annual depletion of the water supply. Net evaporation may be used to measure the weather induced demands on open water bodies.

**REPORTED PARAMETERS:** Parameters to be used are:

1) Net Evaporation (mm) = Gross Evaporation - Precipitation
2) Moisture Stress = Actual Evapotranspiration - Potential Evapotranspiration
3) Five year running mean expressed graphically for 1) and 2) above, on a time series of five year running means for the full period available at each weather station. Limits must be defined for the sustainability of the current system for each region represented by the station.

**SPATIAL SCALE:** The moisture stress data should be calculated on the basis of land-based regions such as the Land Resource Region (LRR) proposed by Dumanski et al at the Centre for Land and Biological Resources Research (CLBRR) for the Prairies.

The net evaporation may be calculated on an LRR base.

**TEMPORAL SCALE:** For the purpose of measuring moisture stress a soil moisture model is required which would run year round using daily data. Some existing models can be run on a weekly basis if the input data is available. The stress values are accumulated over the growing season based on the simulation of moisture demand for a principle field crop growing in the region. The accumulated stress values may be compared from season to season or long term as suggested above.

Net evaporation may be calculated on a monthly time step and accumulated for the year. Since most of the evaporation occurs between May and October a calender year could be used to accumulate annual values for comparing annual variability and long term trend analysis.

**OPTIONS FOR DIS-AGGREGATION:** The moisture stress may be calculated for specific crops depending on their growth characteristics and moisture demands.

Net evaporation may be calculated for small to large water bodies and may, depending on the formula and adjustments required, generate daily, monthly and seasonal values.

**LINKAGE WITH OTHER ISSUES:** The stress indicatorl proposed here define the net relationship between the water supply and the demand based on weather and the characteristics of plants and open water bodies. These indicators relate to all the water supply indicators including groundwater, water quality, soil moisture, crop development and ground cover, irrigation water supply and demand and state of the soil resource (nutrient demand, stubble cover, organic matter).

**DATA SOURCES:** Gross evaporation from open water bodies may be calculated using a number of methods. The most practical and the simplest method is empirical formula. The Meyer formula is suggested here as it is used in the Prairies and has a wind component. Net evaporation would be calculated by subtracting the precipitation recorded at the site.

Actual and potential evapotranspiration are calculated using the Baier and Robertson method in the Versatile Soil Moisture Budget. Derivations of this work are used throughout the Prairies. The VSMB is also used in other parts of Canada.

**NATURE AND EXTENT OF INTERPRETATION:** These indicators can be easily interpreted and easily understood by users and are applicable across Canad The moisture stress will relate to vegetative growth and crop yields. Net evaporation will illustrate the demand on open water bodies due to weather and climatic conditions.

**FEASIBILITY FOR DEVELOPMENT AND NEXT STEP:** These stress indicators are currently used on the Prairies. Some discussion will be necessary to decide which empirical equations should be used. Weather stations need to be identified across Canada. These stations should likely include the reference climate station network and these will hopefully include the Agriculture Canada Research Station weather stations.

Remote sensing methods such as the NOAA Normalized Difference Vegetative Index are becoming increasingly more useful as the data records increase and relationships between the data and plant growth and yield, for example, are developed. The application of this method should be considered.

## APPENDIX 7.1-3: PERCENT AGRICULTURAL LAND WITH SUBSURFACE DRAINAGE

**INDICATOR:** Percent of Agriculture Land with Subsurface Drainage.

**RATIONALE AND POLICY RELEVANCE: To** provide an indication of the extent of subsurface drainage in use to manage water quantity on agriculture land.

This indicator, in conjunction with others, will be useful in addressing policy questions dealing in agricultural management practices and their impact on the sustainability of Canada's water and soil resources.

**LINKAGE WITH OTHER ISSUES:** Where there are a number of policy questions that are concerned with the impact of production practices on environmental sustainability of Canada's Soil and Water resources, this indictor will also be useful in addressing the issues of Water Quality and Agricultural Soil Resources.

**REPORTED PARAMETER(S) AND MEASUREMENT UNITS:** The following parameters will be required to calculate the percentage of agricultural land with subsurface drainage.

- total area of agricultural land
- area of agricultural land with subsurface drainage

**POTENTIAL SPATIAL AND TEMPORAL SCALE:** This indicator is applicable to most regions of Canada.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** Initial Development of the indicator will depend on the availability of base line data on the present area of agriculture land with subsurface drainage. It is known that some provinces have been keeping this information, however, more inquires will have to be made to see just how available the information is across Canada. Where the necessary information is not currently available, projects will have to be carried out to establish the base line data.

To maintain the indicator's parameters, an annual monitoring of subsurface drainage installations and changes to agricultural land area will have to be established. Development of the indicator could be in the medium term.

## APPENDIX 7.1-4: PERCENT OF AGRICULTURAL LAND IN IRRIGATION

**INDICATOR:** Percent of Agriculture Land in Irrigation.

**RATIONALE AND POLICY RELEVANCE:** To provide an indication of the extent of irrigation in use to manage water quantity on agriculture land.

This indicator, in conjunction with others, will be useful in addressing policy questions dealing in agricultural management practices and their impact on the sustainability of Canada's water and soil resources.

**LINKAGE WITH OTHER ISSUES:** Where there are a number of policy questions that are concerned with the impact of production practices on environmental sustainability of Canada's Soil and Water resources, this indicator will also be useful in addressing the issues of Water Quality and Agricultural Soil Resources.

**REPORTED PARAMETER(S) AND MEASUREMENT UNITS:** The following parameters will be required to calculate the percentage of agricultural land in irrigation.

- total area of agricultural land
- area of agricultural land in irrigation

**POTENTIAL SPATIAL AND TEMPORAL SCALE:** This indicator is applicable to most regions of Canada.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** Initial Development of the indicator will depend on the availability of data on the area of agriculture land in irrigation. Inquiries will have to be made to individual provinces to determine just how available the information is across Canada. Where the necessary information is not currently recorded, then systems will have to be established to record, on an annual basis, the area in irrigation.

## APPENDIX 7.1-5: AVAILABLE SOIL MOISTURE

**INDICATOR:** Available Soil Moisture

**RATIONALE AND POLICY RELEVANCE:** To provide producers, extension specialists, and policy makers with a basic measure of stored water for crop use. This information is very important in the drier regions of the prairies because it influences cropping intentions (summerfallow versus recropping) and related decisions (fertilizer/chemical application, fall tillage). The status of soil moisture reserves (fall and spring) can have a major impact on the risk of soil erosion, salinity and drainage problems. This indicator is therefor especially useful for policy decisions due to it's advance warning ability.

**LINKAGE WITH OTHER ISSUES:** Since there is a strong correlation between soil moisture reserves and land management practices, this indicator is linked with several issues associated with environmental sustainability (wind and water erosion, salinization, drainage, surface and groundwater contamination, impact on greenhouse gases). Soil moisture reserves influence cropping intentions and therefore can have an impact on other issues or programs such as crop insurance, drought support, and rebates on input costs. There are also linkages with other resource issues including precipitation, soil quality, wildlife habitat, and irrigation water requirements. The moisture stress index proposed in appendix B uses a soil moisture model to determine moisture shortfalls during the growing season.

**REPORTED PARAMETER(S) AND MEASUREMENT UNITS:** Soil moisture reserves have been reported on provincial maps in terms of depth of moist soil (field capacity) with descriptive terms of very low, low, medium, or high. With some knowledge of soil texture, producers or extensions specialists can easily estimate the quantity of available water for crop use in the soil rooting zone. Regional soil moisture models are used to track snow accumulation and spring infiltration to estimate spring soil moisture levels. More accurate and detailed soil moisture maps could be prepared with additional field measurements in conjunction with precipitation records.

**POTENTIAL SPATIAL SCALE(S):** Available soil moisture information is most important in the drier regions of the prairies, but may also be of value in other regions of the country where drainage issues are of some consequence.

**PROPOSED TEMPORAL SCALE(S):** At present, soil moisture maps are prepared by provincial extension agencies in the fall (Oct/Nov) and spring (April/May) of each year. This activity and publication of maps has occurred for the last 10-15 years and should continue. Some assessment of client use is required.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** Available soil moisture status is of considerable practical importance to the agricultural industry. Since soil moisture is also an important environmental indicator, there should be greater coordination among interested agencies to produce the most accurate and useful soil moisture maps. Greater effort in this regard is necessary.

## APPENDIX 7.1-6: SUSTAINABLE YIELD INDICATOR (SYI) FOR SURFACE WATER

**INDICATOR:** Ratio of licensed surface water use to sustainable yield.

**RATIONALE AND POLICY RELEVANCE:** The sustainable water yield must exceed the licensed water use if the water use is to be sustainable. This is particularly true in the case of agriculture which, in the event of water shortages, is often viewed as a low priority use. If agricultural water uses are to be sustainable, the ratio must remain well below one. The ratio of licensed water use to sustainable yield can also be compared over time to determine how quickly ratio is changing. This has significant policy implications, particularly in basins where the SYI ratio is approaching one -- the limit of development for consumptive uses.

The indicator can be used to help set sectoral water use limits. These limits will help ensure that a basin does not become overcommitted, thereby limiting development to that levels that are sustainable.

**LINKAGE WITH OTHER ISSUES:** This indicator is linked to water quality in that a high ratio will indicate heavy use and probably poor water quality.

**REPORTED PARAMETER(S) AND MEASUREMENT UNITS:** The calculation of the SYI indicator will require collection of licensed water use data and sustainable yield data, both of which can be expressed as a volume and measured in cubic metres. The SYI indicator is expressed as a ratio and, as such, is a dimensionless unit.

**POTENTIAL SPATIAL SCALE(S):** This indicator could be calculated for each river basin. By grouping basins together, the indicator could be used to report on the sustainability of irrigation in larger regions (e.g. prairies). Care must be used to ensure that sustainable yields for areas or regions where irrigation is not practised are not included in the calculation of this indicator.

**PROPOSED TEMPORAL SCALE(S):** Barring a significant hydrologic event (e.g. 1:500 event) or the addition of new storage or significant operating changes to a reservoir, there will be no change in the sustainable yield of a river system. Water use, however, should gradually increase in most regions. Unless the region is approaching the limit of development, calculations done every three to four years should suffice.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** It is feasible to develop this indicator. Licensed water use figures are generally available for all consumptive uses for each major river basin. This portion of the indicator could be improved by using actual water use rather than licensed use data. Unfortunately, actual water use data is not readily available and is both expensive and time consuming to generate.

Sustainable yield figures are somewhat more difficult to obtain than licensed water use. The lowest recorded flows provide a crude estimate of the sustainable yield. Recorded flows, however, do not take into account the profound influence that reservoirs and operating procedures have on the sustainable yield -- particularly in the prairie region.

## APPENDIX 7.1-7: SUSTAINABLE YIELD INDICATOR (SYI) FOR GROUNDWATER

**INDICATOR:** Sustainable Yield Indicator (SYI) for Groundwater.

**RATIONALE AND POLICY RELEVANCE:** Sustainable groundwater development requires that cumulative withdrawals from an aquifer must not exceed the amount of available recharge. Accordingly, aquifer withdrawals less than or equal to the available recharge are sustainable. For groundwater to be sustainable, SYI values, expressed as yield/recharge, should be less than one. In the absence of aquifer specific allocation plans within provinces, agreement on recharge estimation would be required. An upper bound (liberal) estimate is about 5 percent of annual precipitation could be used as a general case of the upper limit.

**LINKAGE WITH OTHER ISSUES:** This indicator is linked to groundwater hydrograph data and trend indicator.

**REPORTED PARAMETER(S) AND MEASUREMENT UNITS:**

- Assuming areal recharge is no more than 5 percent of annual precipitation, then aquifer recharge potential can be universally expressed as a function of climate (cubic metres per sq. kilometre per year).
- Well yields obtained from provincial data banks and individual farm wells (estimated from typical use volumes if data not available - expressed as cubic metres per square kilometre per year).
- Resultant sustainable yield index (SYI) can be prepared to show ratio of well yield to recharge (dimensionless).

**POTENTIAL SPATIAL SCALES:** Sustainable yield index could be displayed as contours of SYI index values derived from well data archives in provincial data banks. Display format would be on a 1:250,000 scale. Care should be taken to prevent inclusion of inactive wells (ie. wells which have been archived, but long since abandoned. Attempts should be made to display conditions for major regional aquifers where possible.

**PROPOSED TEMPORAL SCALES:** Updated maps prepared as required from new well data as these become available. Regional updates might be best carried out over every five or so years in consideration of the data gathering and digital entry processes in each provincial jurisdiction.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** The input data for the calculation of SYI values would appear to be easily applied and universally available. Their ultimate treatment in a GIS environment, which is becoming a popular data analysis and mapping tool, and the fact that many groundwater data bases resident with management agencies are readily available, make this a potentially attractive, flexible approach in exploring groundwater sustainability.

## APPENDIX 7.1-8: GROUNDWATER LEVELS

**INDICATOR:** Groundwater Levels - Hydrograph Trend Analysis.

**RATIONALE AND POLICY RELEVANCE:** Groundwater levels are a direct measure of groundwater volumes held in storage. Water level trends developed by collecting and plotting key indicator data (ie. Spring minimum water levels for long term trends and medium monthly water level data for annual trends) are tools which, with the separation of climatic factors, permit the evaluation of the status of groundwater systems as a consequence of groundwater use. Most provinces have ongoing aquifer monitoring programs, some in digital format, in key aquifer settings.

**LINKAGE WITH OTHER ISSUES:** There is a linkage to climate and surface water conditions.

**REPORTED PARAMETER(S) AND MEASUREMENT UNITS:** The data is usually collected as point data (manual collection) or digital/analog continuous recorder data. Representation is either in digital or graphical form.

**POTENTIAL SPATIAL SCALES:** Hydrograph data available for major aquifers at strategic locations and at variable depths. Shallow hydrographs are most responsive and sensitive to climate and drought conditions.

**PROPOSED TEMPORAL SCALES:** Meaningful trend analysis requires a monitoring commitment of at least 10 years to reconcile natural and anthropogenic factors. Trends are shown on an annual basis with a frequency of measurement of at least once per month.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** Standard recorders and methods of data archiving are relatively common place. Analysis would be facilitated if water level data and climatic stations were in close proximity to each other, and if data were in digital format. Manual/graphical plots would require potentially moderate human resources commitment to convert to appropriate format.

## APPENDIX 7.1-9: RELATIVE IRRIGATED AREA BY SYSTEM EFFICIENCY

**INDICATOR:** Relative irrigated Area by System Efficiency

**RATIONALE AND POLICY RELEVANCE:** Agriculture is seen by many as a big consumptive user of the water and competing directly with other resource users such as fisheries. In some regions agriculture is considered to be wasting water by not using the most efficient application methods available or scheduling application to match crop needs.

An assessment of the trends in irrigated acreage is relevant to the promotion of water use efficiency and use of water per unit of production. An increase in the percentage of land irrigated by efficient irrigation systems would indicate a trend towards more efficient use of the water resource.

**REPORTED PARAMETERS:** Parameters to be used are:

| | Efficiency (%) |
|---|---|
| Flood | 30 - 50 |
| Travelling Gun | 50 - 70 |
| Centre Pivot - sprinkler | 60 - 70 |
| Centre Pivot - spray nozzles | 60 - 70 |
| Sprinkler - handline, wheelline, stationary gun | 50 - 70 |
| Sprinkler - solid set overtree or undertree - including microsprinkler | 55 - 75 |
| Trickle or drip irrigation | 75 - 90 |
| Other systems | |

All parameter should be measured in hectares. Data should be collected on a provincial basis.

**SPATIAL SCALE:** The data should be collected on a provincial basis.

**TEMPORAL SCALE:** Changes in irrigated areas would not significantly change on a yearly basis. The indicator should be monitored every five years.

**OPTIONS FOR DIS-AGGREGATION:** Irrigated land base can also be identified by crop type. Combining the type of irrigation system used with the crop grown will identify which sectors an improvement in water use efficiency is achieved.

**LINKAGE WITH OTHER ISSUES:** Possible linkage with Agriculture Soil Resources Issue. The sustainability of the agricultural land base and management of land and soil to enhance productive capacity is dependent on the availability and wise use of water.

**DATA SOURCES:** The Census of Agriculture is the best method of data collection. Changes in the Census structure will be required to ensure accurate data is collected to provide a good indicator.

**NATURE AND EXTENT OF INTERPRETATION:** An increase or change in irrigated land base does not tell why the change is taking place. The driving force behind the change may have nothing to do with efficient water user for some crops. Also a change in system type does not equate into more efficient water use as system management is not being measured. An irrigation system efficiency also needs to be identified for each system type in order to interpret increased efficiency. A consensus on the efficiency figure to be used must be established. (The system efficiencies provided under reported parameters provides a range of efficiencies that are possible for various system types.) Better management of irrigation systems in the future may also increase efficiencies for all systems.

**TIME FRAME:** The indicator can be developed in time for the next agriculture census. Input into the census is required to ensure good data is received.

Development of the indicator could be in the medium term.

## APPENDIX 7.1-10: COST OF IRRIGATION WATER

**INDICATOR:** The cost of a given volume of irrigation water.

**RATIONALE AND POLICY RELEVANCE:** Irrigation represents the largest agricultural consumer of water. The sustainability of irrigation as an agricultural enterprise has been debated for some time. The cost of irrigation water is a significant factor in helping determine the volumes of water used and the efficiency of its application. Given that the supply of water is finite, irrigation must use water efficiently if it is to be sustainable. In this way, cost can be used as an indicator of irrigation sustainability.

The cost charged of irrigation water can be compared with the cost in other sectors (e.g. hydro-electric power generation, recreation, municipal). The cost can also be compared over time to determine if it is increasing. Given that irrigators tend to be heavily subsidized through an inordinately low cost for water, increasing costs would indicate a move toward a more sustainable form of agriculture.

The indicator can be used to help set water pricing policies to encourage appropriate level of irrigation development and ensure that water used in irrigation is used efficiently.

**LINKAGE WITH OTHER ISSUES:** A suitable cost of water will help ensure that it is used efficiently.

Efficient use will help minimize environmental impacts associated with irrigation, including those on soils and the quality of groundwater and irrigation return flows. In this respect, water pricing can be used indirectly as an indicator of soils and water quality. Using cost as an indicator also facilitates a comparison of costs paid by the agricultural sector with those paid by other sectors.

**REPORTED PARAMETER(S) AND MEASUREMENT UNITS:** $/cubic metre

**POTENTIAL SPATIAL SCALE(S):** Costs will vary from region to region. They could be amalgamated to produce a national indicator by calculating the average or weighted average depending on the volume used or the number of acres irrigated.

**PROPOSED TEMPORAL SCALE(S):** Because pricing is a policy decision, their is no "natural" temporal variation. As a result, costs could be reported annually. However, it is unlikely that significant changes would occur from one year to the next. A three or four year time scale would be more appropriate.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** Cost data is available for most irrigation projects and could be compiled relatively easily. Finding a way of standardizing the cost determination systems would improve the accuracy of the indicator but add a considerable degree of complexity.

## APPENDICES OF POTENTIAL LAND AND SOIL RESOURCES INDICATORS

1. Land Conversion
2. Soil Degradation Risk
3. Soil Quality
4. Crop Yield
5. Soil Cover/Management
6. Adoption of Soil Conservation Practices
7. Nutrient Balance
8. Soil Contamination

## APPENDIX 7.2-1: LAND CONVERSION INDICATOR

**RATIONALE AND POLICY RELEVANCE:** Because Canada's supply of agricultural land is finite, a measure is needed which tracks trends in the stock of farmland. The goal is to minimize the total stock of agricultural land, particularly prime farmland, converted to non-agricultural uses.

**LINKAGE OF THE INDICATOR WITH OTHER ISSUES:** There is a linkage to water quality in that the converted use often imposes vastly different drainage characteristics than those that prevailed under agriculture. There would be more rapid surface drainage to rivers and lakes and potentially much less drainage to groundwater.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** Indicator reports trends in stock of agricultural land, either by: i) type of land use (total agricultural land, total cultivated land, total irrigated land, total cropland, and total rural non-agricultural land), ii) agricultural land capability (i.e. Canada Land Inventory or Soil Quality Elements), and iii) intersection of land area by agricultural capability class (or soil quality elements) with municipal or provincial land use zoning boundaries.

**POTENTIAL SPATIAL SCALE(S):** This indicator could be reported nationally at scales of 1:2M or smaller as well as at regional and local scales of 1:1M and larger.

**PROPOSED TEMPORAL SCALE:** Every 5 years.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** Indicators by type of land use could be developed for national purposes in the short-term from Census of Agriculture data. Indicators for regional or local use could be developed in the medium term by class of farmland using a combination of Census of Agriculture, provincial data and remote sensing (radar, NOAA AVHRR).

**TIME-FRAME FOR INDICATOR DEVELOPMENT:** Medium term.

## APPENDIX 7.2-2: SOIL DEGRADATION RISK INDICATOR

**RATIONALE AND POLICY RELEVANCE:** The requirement to maintain the nation's supply of high quality land for food production is dependent, in part, on preventing degradation to the quality of this resource. Indicators that measure or predict risk or susceptibility to change in soil quality due to wind and water erosion, salinization, and compaction provide a reliable assessment of stress or pressure on the soil resource base induced by land management practices. In that analysis of risk involves consideration of the inherent soil attributes and associated climatic conditions, and land management practices involving soil cover, tillage, traffic, etc., it is a superior indicator to soil management indicators (i.e. soil cover) used alone. The policy goal is to minimize land area at risk to soil degradation from various soil-modifying processes.

**LINKAGE OF THE INDICATOR WITH OTHER ISSUES:** This indicator will also measure risk to change in the capacity of the soil/land to provide an environmental filter for chemicals (fertilizers and pesticides) and wastes (manure, sewage effluent, and sludge) added to agricultural land. Similarly, it will measure trends in risk to changes in the capacity of soil/land to regulate and partition the flow of water and air by providing measures of the nature and magnitude of liquid and gaseous flows from the soil to surface and groundwater and to the atmosphere.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** Trends in area of land affected by or vulnerable to: i) wind and water erosion, ii) change to soil organic matter, and iii) soil salinity.

**PROPOSED SPATIAL SCALE(S):** Analysis should be conducted at scales of 1:1M (SLC), or larger, to accommodate diversity in soil and land management. This data would then be aggregated and reported at 1:2M (LRA), or smaller scales.

**PROPOSED TEMPORAL SCALE:** This indicator should be summarized and reported in the year following Census of Agriculture.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** A series of wind and water erosion risk maps have been prepared for the entire country using the Soil Landscapes of Canada (SLC) database. They essentially rate the risk for bare, unprotected soil using the Universal Soil Loss Equation (USLE) and the Wind Erosion Equation (WEQ), with adjustments for uncultivated land and the degree of protection from erosion provided by usual crop management within the cultivated area. This procedure could be repeated to coincide with each Census of Agriculture. The system could be improved with revised equations for water and wind erosion (RUSLE and REQ) and with more precise land use information such as can be provided by fall Landsat (TM) image-derived residues. Output from these equations is most appropriately presented as numerical risk indices or risk classes. Reporting in absolute terms (i.e. tonnes/ha removed) may be possible when simulation models (WEPP and WERM) currently under development by USDA are available. Improved capabilities are emerging to measure susceptibility to change in soil organic matter, structure and salinity through continued improvements to the CENTURY model for the former and algorithms based on SEEP/W for the latter. Stress/strain relationships developed for a Municipality in Ontario could be used for the assessment of soil structure.

**TIME-FRAME FOR INDICATOR DEVELOPMENT:** Short to medium term.

## APPENDIX 7.2-3: SOIL QUALITY INDICATOR

**RATIONALE AND POLICY RELEVANCE:** The requirement to maintain the nation's supply of high quality land for food production is dependent, in part, on preventing degradation to the quality of this resource. Direct or indirect measures of soil attributes that are sensitive to change with land management is the ultimate approach to tracking trends in soil quality. The policy goal is to promote land management practices that minimize on-site soil degradation and off-site alteration to the hydrosphere, biosphere and atmosphere.

**LINKAGE OF THE INDICATOR WITH OTHER ISSUES:** This indicator also measures the change in the capacity of the soil/land to provide an environmental filter for chemicals (fertilizers and pesticides) and wastes (manure, sewage effluent, and sludge) added to agricultural land. Similarly, it will reflect changes in the capacity of soil/land to regulate and partition the flow of water by providing measures of the kind and extend of materials moving below the rooting zone and being removed from the soil through surface flow.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** Soil quality can be measured by the selection of key attributes where trend changes can be measured over one to ten years. Because many soil attributes are inter-related, the key soil attributes can often be estimated from other attributes. Currently, this indicator would report trends in land area affected by soil salinity and change in soil organic matter. Aggregate or composite units (available porosity, nutrient retention, chemical and physical rooting conditions) for assessing soil quality for crop production have been developed. These units, termed Soil Quality Elements, are suitable for national assessments in that they provide a broad assessment of soil quality. Larger scale assessments of soil quality change can then be conducted by applying soil-modifying processes to achieve a soil quality index for the crop production function.

**PROPOSED SPATIAL SCALE(S):** Analysis should be conducted at scales of 1:1M (SLC), or larger, to accommodate diversity in soil and land management. This data-would then be aggregated and reported at 1:2M (LRA), or smaller scales.

**PROPOSED TEMPORAL SCALE:** This indicator should be summarized and reported in the year following the Census of Agriculture.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** In the short term, this indicator would be based on predicted change to soil organic matter and soil salinity Over the medium term, it would be expanded to incl trends in soil structure and soil contamination. Reliable estimates of the extent and distribution of soil salinity have been prepared for the prairie provinces and a soil carbon map has been prepared for Canada. Change to reported levels would be based on land management data from Census of Agriculture, using the predictive capabilities embodied in CENTURY and salinity simulation models. The Soil Quality Benchmark Sites and associated salinity monitoring sites would be used as a basis for validation of these estimates. The capability of Census of Agriculture databases to define land management for meaningful soil-landscape units can be improved with remote sensing imagery. The indicator process would be better served by linking the various soil attributes into more comprehensive measures, such as the Soil Quality Elements described above for the crop production function. Comparable elements would be derived for the environmental functions. Ideally, an even more holistic indicator of soil quality should be developed. Measures of ecosystem and soil health as reflected in surface temperatures or as ratios of energy input to useable output product should be considered for long-term development.

**TIME-FRAME FOR INDICATOR DEVELOPMENT:** Short to medium and long term.

## APPENDIX 7.2-4: CROP YIELD INDICATOR

**RATIONALE AND POLICY RELEVANCE:** Crop yield is the result of interactions among soil, weather and management inputs. Added stress on any of these variables is usually reflected in decreased yields or added yield variability. Increased variability of yields is an indicator that the risk of crop production is increasing, usually resulting in increased production costs. There is a concern that soil degradation has or will result in reduced yield or reduced biological yield potential. Alternatively, it could result in greater yield variability. The policy goal is to avoid reductions to historic yield potentials and variability in these potentials.

**LINKAGE OF THE INDICATOR WITH OTHER ISSUES:** Decreased yield and increased yield variability is an immediate signal of either inappropriate land management, soil degradation or climate change. Changes in yield levels can have serious implications for costs of production and for net farm profits. Knowing the causes of any yield decreases or added variability is important for developing proper ameliorative measures and to formulate policy initiatives to overcome the yield losses.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** Yields of the major cultivated crops have to be evaluated in terms of total harvestable product or biomass. Long-term trends of yield are much more important than average yields because the latter screens out the variability which is necessary to estimate risk, and risk is an important indicator of sustainability. It is important to evaluate yields at various levels of management inputs. Yield variability at top management is beyond the ability of the farmer to control, therefore, it may be indicative of soil degradation or deteriorating climate. Yields also have to be evaluated in relation to the inherent biological production potential of an area, because the more yields are pushed to approach these potentials the greater the probability of serious problems, i.e. the lower the margin of management error. An international standard is that areas should be put on watch if yield levels approach 70% of biological potential (some areas in Canada are already beyond these levels).

**PROPOSED SPATIAL SCALE:** Analyses have to be conducted at regional scales to compare variation of risk with regional biological production potentials and for individual soils, or groups of soils, to provide estimates of where the greatest concerns are likely to be found. The results could be aggregated and reported at 1:2 M (LRA) or larger.

**PROPOSED TEMPORAL SCALE:** This indicator should be summarized and reported in the year following each Census of Agriculture.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** Trends of crop yields and variability can be developed from long-term experiments, from other long-term yield records such as crop insurance and related programs and from yield simulations using crop growth models. Crop insurance records, particularly those which collate both yield and management information, are of the greatest immediate value. Crop growth models offer some potentials for the future, but the models have to be carefully validated for the most important agro-environments of Canada. This can be a substantial amount of work. Long-term experimental data should be used but likely their biggest value will be in validating other estimates; the number of such experiments is not large enough to provide valid regional assessments.

**TIME-FRAME FOR INDICATOR DEVELOPMENT:** Short to medium term. A number of studies have already provided preliminary indicators and they have developed some of the necessary protocols for further development.

## APPENDIX 7.2-5: SOIL COVER / MANAGEMENT INDICATOR

**RATIONALE AND POLICY RELEVANCE:** Providing protection to the soil surface to minimize wind and water erosion can minimize soil loss and consequent potential loss in soil productivity. The policy goal is to promote land management practices that provide maximum protection from wind and water erosion, surface run-off and leaching to groundwater.

**LINKAGE OF THE INDICATOR WITH OTHER ISSUES:** As was stated for the soil quality indicator, soil cover will also reflect the capacity of the soil/land to provide an environmental filter for chemicals (fertilizers and pesticides) and wastes (manure, sewage effluent, and sludge) added to agricultural land. It will also reflect the capacity of soil/land to regulate and partition the flow of water by evaluating the kind and extend of materials moving below the rooting zone and being removed from the soil through surface flow. As such, this indicator also relates to surface and ground-water quality.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** This indicator would be reported in terms of area of agricultural land having sufficient cover to reduce the extent and degree of soil degradation to a level that does not impair current or future capacity for crop production. Reporting would include the following: i) area of fallow (winter and summer) as a percent of total cultivated land area or total seeded area, ii) area of land sown to winter cover crop, iii) area of monoculture cropping as a percent of total cultivated land area, iv) area of forage crops in rotation as a percent of total cultivated land area, v) area of agricultural land in which crops are seeded directly into standing stubble as a percent of total seeded land area, vi) area of marginal agricultural cultivated lands returned to permanent cover as a percent of total cultivated marginal lands in the area, vii) Km. of field shelterbelts planted each year, viii) area of agricultural land intentionally burned each year as a percent of total cultivated land area.

**PROPOSED SPATIAL SCALE(S):** Analysis should be conducted at scales of 1:1M (SLC), or larger, to accommodate diversity in soil and land management. This data would then be aggregated and reported at 1:2M (LRA), or smaller.

**PROPOSED TEMPORAL SCALE:** This indicator would be summarized and reported in the year following Census of Agriculture.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** This indicator would be developed from Census of Agriculture, augmented with thematic mapper imagery as required, reported nationally using: i) area of summerfallow, ii) area of land sown to winter cover crop, iii) area of (winter) fallow, iv) area of chemical fallow, v) area of direct seeding into standing stubble, vi) area of land converted to permanent cover, vii) area of row cropping, viii) area of forage in rotation, ix) area of monocultural cropping.

**TIME-FRAME FOR INDICATOR DEVELOPMENT:** Analysis and summary of soil cover indicators based on 1991 Census of Agriculture are planned for completion in 1994-95.

## APPENDIX 7.2-6: ADOPTION OF SOIL CONSERVATION PRACTICES INDICATOR

**RATIONALE AND POLICY RELEVANCE:** The extent or rate of adoption of soil conservation practices has an important impact on the extent and severity of soil degradation and other environmental impacts. The rate of adoption may impact on crop yield and input requirements in the short and the long term. This indicator provides an opportunity to directly address the question "To what extent are land management and cropping practices which enhance the productive capacity of the land and soil resource base being employed?" It also provides a measure of successes in efforts to raise awareness and transfer technology.

**LINKAGE OF THE INDICATOR WITH OTHER ISSUES:** In that the adoption of practices such as maintaining standing stubble until seeding time, be it following a crop or summerfallow, implies more intensive use of pesticides and fertilizers as well as impacting on the regulation and partitioning of surface water, this indicator has relevance to both the water quantity and water quality issues.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** This indicator reports the number of farms employing soil management practices that have a distinct soil conservation benefit or the percentage or ratio of area under soil conserving to area of conventional practices (i.e. percentage or ratio of cultivated land where crops are direct seeded into standing stubble, including land that was fallowed as a percent of total seeded land area to total cultivated area.

**PROPOSED SPATIAL SCALE(S):** Analysis should be conducted at scales of 1:1M (SLC), or larger, to accommodate diversity in soil and land management. This data would then be aggregated and reported at 1 :2M (LRA), or smaller.

**PROPOSED TEMPORAL SCALE:** This indicator should be summarized and reported in the year following Census of Agriculture.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** Development in the short term would be based on data 52 such as area of chemical summerfallow and area of direct seeding into standing stubble from 1991 Census of Agriculture. Regional and local analysis would require augmenting these data with Landsat (TM).

**TIME-FRAME FOR INDICATOR DEVELOPMENT:** Indicator development, analysis and summary from 1991 Census of Agriculture at 1:2M scale will be completed in 1993-94. Analysis at larger scales will be undertaken in 1994-95.

## APPENDIX 7.2-7: NUTRIENT BALANCE INDICATOR

**RATIONALE AND POLICY RELEVANCE:** Judicious application of organic and inorganic fertilizer amendments generally increases crop yields and net economic return for producers. Under-utilization of these amendments results in soil "mining" -- depletion of the soil's natural fertility through the removal of nutrients by harvested crops. Over-utilization creates a surplus of nutrients in the soil, thus wasting amendment supplies, incurring unnecessary costs to farmers, and increasing the risk of contamination of water resources and destruction of the stratospheric ozone layer. Under utilization contributes to soil degradation and to a decrease in the productive capacity of the soil. The policy objective is to promote nutrient amendment practices that maintain the proper nutrient balance in soils.

**LINKAGE WITH OTHER ISSUES:** Over-application of amendments resulting in surplus nutrients in the soil can contribute to nitrogen and phosphorus contamination of surface and groundwater through leaching and runoff and to destruction of the stratospheric ozone layer through denitrification. Organic amendments, such as manure and legumes, could replace or reduce the use of commercial fertilizers in low input systems. This would make on-farm waste recycling more efficient and reduce the energy subsidy (mainly from fossil-fuels).

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** A nutrient "balance sheet" would be generated by determining the differential between the amount of N and P put into and taken out of a soil. Input measurements (kg/ha) include organic amendments (manures and other organic wastes), legumes, crop residues, and wet and dry deposition of pollutants. Output measurements (kg/ha) include harvested crops, leaching and erosion losses, and losses to the atmosphere. If a large differential favours outputs over an extended period, the soil will be mined, and the potential for the deterioration of soil quality will increase. If inputs *exceed* outputs plus the amount of nutrients that can be stored by the soil, the risk of environmental contamination increases.

**PROPOSED SPATIAL SCALE:** A nutrient balance sheet can be produced at many levels: field, farm, township, county, region. Data for small land units may come from direct analysis of the soil and from farm records. Data for larger land units may come from Statistics Canada, provincial extension agencies, Crop Insurance programs, fertilizer dealers, etc.

**PROPOSED TEMPORAL SCALE:** A minimum time-frame of 10 years is needed to evaluate trends and fluctuations of nutrient deficits and surpluses, and annual crop yields over a series of crop cycles. However, poor crop yield can point to a short-term need for increased nutrient input and local groundwater contamination can point to a short-term need for decreased nutrient input.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** Research is required to develop the statistical relationships between the observed changes in soil organic matter levels and the inputs and outputs of production systems for different soil types. Areal estimates of soil organic matter levels, inputs of fertilizer and organic amendments, quantities of nutrients returned to the soil from biological fixation and deposited (wet and dry) and local/provincial estimates of grain, oilseeds, forages, livestock and dairy products and the nutrient content of these products are also required.

**TIME FRAME FOR INDICATOR DEVELOPMENT:** Several years may be needed to obtain, analyze and interpret data from the Census of Agriculture, provincial soil surveys, provincial statistics and fertilizer dealers. More time is needed to account for annual variations in measured parameters and to conduct the research outlined above.

## APPENDIX 7.2-8: SOIL CONTAMINATION INDICATOR

**RATIONALE AND POLICY RELEVANCE:** Chemical inputs to agricultural land come primarily from agricultural pesticides, fertilizers, and non-agricultural waste disposal. Inputs become contaminants when: i) loadings surpass the capability of the soil and its biological processes to render the chemicals harmless to soil organisms or organisms dependent upon soil-based food chains and ii) contaminants run off the soil surface, pass to groundwater or blow away. Unknown or beneficial effects may be caused by some chemicals below the contamination threshold. Some contaminants (cadmium and radionuclides) are essentially non-degradable, and their deposition on land requires tight regulatory control. Others degrade slowly, and persist or are sequestered in soil and water compartments from which they may re-enter the food chain. Although most modern agricultural pesticides degrade quite rapidly, there are occasional problems associated with their accumulation or persistence in the environment (usually, but not exclusively associated with groundwater quality) or in food chains. The policy goal is to maintain the capability of the soil resource to provide high quality food and to minimize negative, non-target environmental impacts arising from the application of chemicals to agricultural land.

**LINKAGE OF THE INDICATOR WITH OTHER ISSUES:** Use of agricultural pesticides, agricultural wastes, and non-agricultural waste disposal may result in leaching to groundwater, surface run-off, atmospheric contamination, reduction of habitat and reduction of biological diversity. Pesticides not applied in accordance with label directions can result in contamination of food products and endanger applicator safety. Interim limits, which already exist for a few soil contaminants, are somewhat arbitrary. Recent efforts under the National Contaminated Sites Remediation Program are directed at establishing new standards for soil contaminants that will be health-based in relation to potentially impacted soil organisms and soil food chains. These efforts may complement indicator development for sustainable soil resources.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** Parameters required to compose this indicator are: i) the names of pesticides or fertilizers used, ii) frequency and amount of application by crop area, iii) numbers of agricultural chemical applicators in a province, iv) primary soil physical chemical characterization parameters, v) location, amount and chemical composition of industrial waste (including sludge), applied to agricultural lands, vi) impact on soil biota, and vii) impact on soil structure. A composite index of soil contamination would be reported, initially, based on application rates of strategic pesticides, fertilizers and wastes.

**PROPOSED SPATIAL SCALE(S):** Analysis should be conducted at scales of 1:1M (SLC), or larger to accommodate diversity in soil and land management techniques. These data would then be aggregated and reported at 1:2M (LRA), or smaller. Additionally, analyses and reporting of effects on soil processes from landscape to pedon scale would be appropriate, and integration and synthesis of data already available at these scales should be possible from current databases.

**PROPOSED TEMPORAL SCALE:** 5 years.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:**

This indicator would rely on data from Census of Agriculture, provincial statistics, agricultural chemical manufacturers, fertilizer dealers, and fertilizer associations to provide information on kind and amount of chemical application. In broad terms, rate of application of agricultural chemicals could be related to regional agricultural intensity that may be extractable from GIS databases. Restrictions on dissemination of proprietary information by manufacturers and dealers will require consultation to obtain this information.

**TIME FRAME FOR INDICATOR DEVELOPMENT:** Medium term.

## POTENTIAL GENETIC DIVERSITY INDICATORS

1. Crop and Livestock Production Diversity Index
2. Crop and Livestock Genetic Diversity Index
3. Crop and Livestock Genetic Preservation Index
4. Soil Bio-Quality/Soil Health
5. Water Bio-Quality/Water Health
6. Biocontrol Index
7. Beneficial Species
8. Non-Crop Soil Cover Index

## APPENDIX 7.3-1: CROP AND LIVESTOCK PRODUCTION DIVERSITY INDEX

**Basis:** - area or number of different crop and animal species contributing to total output.

**RATIONALE AND RELEVANCE:** This indicator reports the area of different crop species and/or numbers of different animal species at an appropriate level (farm, area, regional, national) contributing to total output at that level to measure and encourage diversity of the crop and livestock species used in agriculture. Increased diversity of production can minimize production risk, enhance genetic diversity and promote environmental sustainability. Maintenance of production diversity may be an appropriate goal for certain regions.

**LINKAGE WITH OTHER ISSUES:** Appropriate utilization of Land Resources and Farm Inputs. Support of Wildlife Habitat.

**REPORTED PARAMETER AND MEASUREMENT UNIT:**

- area (ha) of different crop species as a percentage of total area or output of different crops as a percentage of total output (in dollars or by volume)

- number of different animal species as a percentage of total numbers (with appropriate weighting) or output of different livestock as a percentage of total output (in dollars or by volume).

**POTENTIAL SPATIAL SCALE:** Can be measured/ reported at the farm level or developed/ aggregated to regional or national scale.

**PROPOSED TEMPORAL SCALE FOR REPORTING:** In accordance with collection of Census of Agriculture data.

**FEASIBILITY:** Short-term from existing Census of Agriculture data.

Further development and refinement over the medium term of a production diversity "scale" could permit reporting of the % of farms (or areas/regions) and their location with a particular score on this scale to permit examination of where diversity is greatest or has increased/decreased, with policy relevance for promoting environmental sustainability.

## APPENDIX 7.3-2: CROP AND LIVESTOCK GENETIC DIVERSITY INDEX

**Basis:** Number of different cultivars of crop species or breeds of animal species in production.

- acreage amounts and distribution of cultivars of crop species

- populations and distribution of breeds of animal species

**RATIONALE AND RELEVANCE:** Depending on the degree of the inherent genetic diversity across different varieties of major crop species and breeds of livestock species, a measurement of the number of different varieties or breeds contributing to total output for the particular species offers a readily available means to assess genetic resources diversity. This can be supplemented by acreage amounts and distribution of cultivars of crop species and populations and distribution of breeds of animal species to permit estimates of the extent and concentration of particular genetic "make-ups". Enhanced genetic diversity within species can minimize production risk and promote environmental sustainability. The goal would be to have increased cultivar and breed diversity and associated greater genetic diversity within species used in agriculture. This would address concerns that segments of plant and animal agriculture might not be sustainable in the long-term and that the genetic base (diversity) is becoming narrower.

**LINKAGE WITH OTHER ISSUES:** Land resources, Farm Inputs, Yield Variability.

**REPORTED PARAMETER AND MEASUREMENT UNIT**

- for major crop and livestock species, the number of different varieties or breeds contributing to total output as reported in dollars or by volume.
- acreage amounts of cultivars of crop species by appropriate spatial scale expressed as percent of total output.
- populations of breeds of animal species by appropriate spatial scale expressed as percent of total output.

**POTENTIAL SPATIAL SCALE:** Analysis conducted to accommodate diversity between and within agricultural production regions. Data then aggregated to regional or national scale.

**PROPOSED TEMPORAL SCALE FOR REPORTING:** Annually

**FEASIBILITY OF DEVELOPMENT:** Development in short-term from Census of Agriculture Data and seed sales and livestock registry statistics. Periodically (3-5 years), long-term trends should be established and analyzed for the total period where data is available. Other databases of information on parentage of crop and animal species maintained at the national level would contribute to this indicator and also the Genetic Preservation Index.

## APPENDIX 7.3-3: CROP AND LIVESTOCK GENETIC PRESERVATION INDEX

**Basis:** amount of genetic stocks (germplasm) and their diversity related to agroecosystem production of crop and livestock species and other products held in genebanks, breeders collections, industry and public sector.

- numbers, frequency and distribution/location of wild relatives (and land races) of crops and wild progenitors of domestic breeds of animals, including those species maintained in-situ and those with potential in future crop and animal production.

**RATIONALE AND RELEVANCE:** For crops, a broad genetic base within the cultivated species is essential if breeding programs are not only to enhance yields but to develop varieties better adapted to environmental conditions and with improved resistance to pests and diseases, and furthermore with qualities that satisfy client and consumer demand. Very few of Canada's major crops originated here; preservation of the genetic diversity of domesticated plants and wild relatives endows Canada with the potential and flexibility to develop superior crop varieties and promote environmental sustainability. Within traditional breeding procedures the best cultivars or lines of one generation are used as parents of the next, thereby progressively narrowing the germplasm base in each generation of selection. It is essential to retain a broad base of plant genetic resources which can be "activated" to enhance significantly the existing limited germplasm "make-up" of cultivars so that sustainability of production and required gains can be assured.

For animals, germplasm resources in Canada and North America are limited compared to global resources and to maintain technology and ensure sustainability of production it is imperative to have a long-term program which involves continual sampling, evaluation and genetic improvement of animals by maintaining and utilizing global germplasm resources. Important considerations are the number of purebred animals registered, genetic variance in populations for key traits, and the present and projected in-breeding level.

In addition to crop and animal species in terms of genetic diversity for Canadian agriculture, microbial genetic resources also need to be considered since progress in basic or applied biological research, including biotechnology, is dependent on the availability of suitable genetic material for study and use.

The overall goal related to -environmental sustainability would be increased genetic diversity represented in germplasm used for agricultural production.

**LINKAGE WITH OTHER ISSUES:** Land Resources, Farm Inputs, Yield Variability, Wildlife.

**REPORTED PARAMETER AND MEASUREMENT UNIT:** -

- Amount (number) and location of genetic stocks (germplasm) related to agroecosystem production of crop species and their wild relatives, including land races, held in genebanks, breeders collections, industry material, public sector, and *in-situ.*

- Amount (number) and location of genetic stocks (germplasm) related to agroecosystem production of livestock species and their wild progenitors held by the public and private sector.

Wherever possible this data should be presented as distinct accessions (genotypes) as opposed to total accessions, particular for genebanks, to better reflect indirectly the degree of genetic diversity.

- Genetic diversity of germplasm related to production of crop species reflected in existing cultivars and genetic resource holdings. Measurement units would be dependent on the methods used to assess this diversity which could include morphological/ phenotypic characteristics and parameters, including response to stressors, and molecular/DNA analysis.

An indirect measurement, particularly indicative of the genetic diversity of cultivars and breeding lines, would be rate of gain in crop yield and this would be best expressed as cost in constant dollars of input per unit of gain to take into account increased/decreased research effort.

- Genetic diversity of germplasm related to production of animal species reflected in existing breeds and genetic resource holdings/sources. Measurement units would be dependent on the methods used to assess this diversity which could include observed genetic variance for key performance and other traits and estimation of genetic and variability "distances" by DNA analysis which would be applicable within and across species or breeds.

Other measurement approaches and parameters would include pedigree information on stocks and the current and projected in-breeding level.

**POTENTIAL SPATIAL SCALE:** Data compiled on a national or, where applicable, international basis.

**POTENTIAL TEMPORAL SCALE FOR REPORTING:** Reporting frequency on a 1-5 year basis with a shorter time scale for amounts of holdings compared to genetic diversity of holdings.

**FEASIBILITY OF DEVELOPMENT:** Short-term for compiling amounts of genetic stocks held in existing collections in public domain and private sector where available and well-documented. Medium term for developing inventories of wild relatives and progenitors. Long-term for genetic diversity evaluation and analysis with the exception of short to medium term for collecting of existing information on pedigrees of animal stocks and crop cultivars and lines. Long-term trends and projections should be established and analyzed for the total period where data is available and this could be up to a 20 year basis.

## APPENDIX 7.3-4: SOIL BIO-QUALITY: SOIL HEALTH INDICATOR

**Basis**: Species richness of representative taxa of saprophagous soil microfungi and mites.

- Trophic structure of soil nematode populations.
- Population density and species richness of earthworms.

**RATIONALE AND RELEVANCE:** Maintaining quality land for food production is dependent on biological activity in soils, to which saprophagous soil microfungi, mites and earthworms are direct contributors. They directly and indirectly effect decomposition and nutrient cycling in soil and contribute to soil structure and bioporosity. Representative genera in these groups are widely distributed across soil types and are proxy groups for soil fauna and saprophytic soil microflora. The biological health of soils also is reflected in changes in the trophic structure of nematode populations. All these groups are highly sensitive to agronomic and forestry practices that affect soil. Species diversity and density are correlated with intensity and type of cultivation and agroecosystem management. Policy relevance is to promote management practices and strategies that sustain soil quality and productivity.

**LINKAGE WITH OTHER ISSUES:** Soil quality, water quality.

**REPORTED PARAMETER AND MEASUREMENT UNIT:**
- Identification of species diversity in representative taxa of mites, earthworms and microfungi.
- Identification of trophic structure of nematode populations.
- Measurements of abundance or biomass per unit area, e.g., topsoil volume (or in relation to soil perturbation).
- Measurement Unit: Species diversity and density/unit area (mites, earthworms, microfungi); trophic structure/population (nematodes).

**POTENTIAL SPATIAL SCALE:** Analysis conducted to accommodate diversity in soil and land management. Data then aggregated to regional or national scale.

**PROPOSED TEMPORAL SCALE FOR REPORTING:** Annually for diversity and abundance/biomass until baseline established. Subsequent to establishing baseline, reporting frequency on 5 year basis.

**FEASIBILITY OF DEVELOPMENT:**
- Taxonomic expertise for mites and microfungi available at CLBRR; need to develop expert systems for rapid identification of representative taxa;
- Taxonomic expertise for earthworms available at London and Lethbridge Research Stations.
- Quantitative sampling expertise available at London and Lethbridge Research Stations;
- Nematode expertise not available in Agriculture Canada;
- Acquisition of baseline data for different soil types would take 2-5 years and personnel; that is, indicator can be developed in Medium to Long Term.

## APPENDIX 7.3-6: WATER BIO-QUALITY / WATER HEALTH INDICATOR

**Basis:** Species richness of representative taxa of water mites, chironomid insects and aquatic plants.

**RATIONALE AND RELEVANCE:** Maintaining quality water for agricultural use and that of the general population is a recognised essential. Species diversity of many insects, mites and plants is highly sensitive shifts in water quality mediated by agronomic and forestry practices that effect the landscape. Representative taxa in these groups are distributed across diverse water sources (groundwater to temporary ponds). Policy relevance is to promote management practices that sustain groundwater quality.

**LINKAGE WITH OTHER ISSUES:** All water quality issues (surface and ground water).

**REPORTED PARAMETER AND MEASUREMENT UNIT:**

- Identification of species diversity of chironomid insects, aquatic mites, and plants
- Measurements of diversity per source of water and per perturbation
- Measurement Unit: Species diversity/unit volume (or, as per Great Lakes Water Quality Measurements)

**POTENTIAL SPATIAL SCALE:** Analysis conducted to accommodate effects of agronomic and human practices on water sources. Data then aggregated to regional or national scale.

**PROPOSED TEMPORAL SCALE FOR REPORTING:** Annual for diversity until baseline established. Subsequent to establishing baseline, reporting frequency on 5 year basis.

**FEASIBILITY OF DEVELOPMENT:**

- Taxonomic expertise for mites, chironomid insects and plants available at CLBRR; need to develop expert systems for rapid identification of representative taxa;

- Sampling expertise available at CLBRR and Canadian universities;

- Acquisition of baseline data for different water sources would take two years and personnel; that is, indicator can be developed in Medium Term.

**APPENDIX 7.3-6: BIOCONTROL INDEX**

**BASIS:** Biocontrol release index.

**RATIONALE AND RELEVANCE:** Maintaining crop yield often is dependent on a balance between pest populations and pest control measures. Previously, most pests have been controlled by formulated pesticides, but negative impacts of pesticides on non-target organisms (including humans), and a Canadian population increasingly aware of chemical sensitivity, means that use of biological organisms (pathogens, parasitoids, predators) to control pest species increases annually. Many crops grown in Canada originated elsewhere, and biocontrol agents for their pests must be imported. In addition, biocontrol agents (e.g., strains of Bt.) are developed in Canada. In all cases release of biocontrol agents and their level of success is closely monitored, as is pest species diversity.

**LINKAGE WITH OTHER ISSUES:** Enhancing crop yield while maintaining environmental quality.

**REPORTED PARAMETER AND MEASUREMENT UNIT:**

- Release data on biocontrol agents and pest species;

- Species diversity of biocontrol agents.

- Indicator reports species diversity of biocontrol agents and pests per region;

- Goal is to increase successful releases of biocontrol agents.

**POTENTIAL SPATIAL SCALE:** Analysis conducted to accommodate diversity in soil and land management. Data then aggregated to regional or national scale.

**PROPOSED TEMPORAL SCALE FOR REPORTING:** Could be summarized and reported annually; more rational time scale - 5 years.

**FEASIBILITY OF DEVELOPMENT:** Data for biocontrol release index available in various regional, provincial and national databases. Short-term.

**APPENDIX 7.3-7: BENEFICIAL SPECIES INDICATORS**

**BASIS:** Species diversity of representative genera of pollinator, predaceous, pathogenic, and parasitoid insects and fungi.

- Relational diversity index of mycorrhizal species diversity and crop yield.

**RATIONALE AND RELEVANCE:** Maintenance of biological resources and biodiversity, especially of beneficial organisms, will help sustain agriculture now and into the future. Utilizing the biofertilization potential of fungi, the biocontrol possibilities within insects and fungi as predators, parasitoids and pathogens, and the pollination benefits of insects, will be essential in enhancing productivity while maintaining or improving environmental quality. Mycorrhiza are intimately associated with both plants and soil, affecting plant growth and soil structure in response to changes in plant biochemistry and soil properties. Representative genera of beneficial groups are widely distributed across agroecosystems. Policy relevance is to promote management practices that sustain crop yield while maintaining environmental quality.

**LINKAGE WITH OTHER ISSUES:** Crop yield, soil quality.

**REPORTED PARAMETER AND MEASUREMENT UNIT:**

- Identification of species diversity in representative taxa for each functional group of beneficial organism.

- Measurements of species diversity per unit area, e.g., per agroecosystem landscape.

- Measurement of mycorrhiza diversity in relation to long-term cropping practices.

**POTENTIAL SPATIAL SCALE:** Analysis conducted to accommodate diversity in agroecosystem management. Data then aggregated to regional or national scale.

**PROPOSED TEMPORAL SCALE FOR REPORTING:** Annually for diversity and abundance/biomass until baseline established. Subsequent to establishing baseline, reporting frequency on 5 year basis.

**FEASIBILITY OF DEVELOPMENT:**

- Taxonomic expertise for predator and parasitoid groups and mycorrhiza available at CLBRR; taxonomic expertise for pollinators and pathogens available at Ag. Canada research stations; need to develop expert systems for rapid identification;

- Sampling expertise available at Agriculture Canada (CLBRR and Research Stations);

- Acquisition of baseline data for different groups would take 2-5 years and personnel; that is indicator can be developed in Medium Term to Long Term.

**APPENDIX 7.3-8: NON-CROP SOIL COVER INDEX**

**BASIS:** Species diversity of representative weed species and native plants.

- Species diversity of permanent cover crop.

**RATIONAL AND RELEVANCE:** Weed species and native plant species often are precise and easily recognised indicators of particular soil conditions, e.g., levels of micro-nutrients. Many weed and native plant species and those used as cover crops can fix nitrogen and improve the nitrogen balance in soil. In addition, their roots bind the soil and they prevent top-soil erosion. Weed and native plant species and species used as cover crops often are widely distributed across agroecosystems. Policy relevance is to promote management practices that enhance soil quality.

**LINKAGE WITH OTHER ISSUES:** Soil quality.
**REPORTED PARAMETER AND MEASUREMENT UNIT:**

- Identification of dominant species of weeds, native plants and plants used as cover crops.

- Measurements of species diversity per unit area, e.g., per agroecosystem landscape.

- Goal: increase use of cover crops that improve soil nutrient content, use of weeds as surface indicators of soil nutrient content, and use of native plants to prevent top-soil erosion.

**POTENTIAL SPATIAL SCALE:** Analysis conducted at farm level. Data then aggregated to regional or national scale.

**PROPOSED TEMPORAL SCALE FOR REPORTING:** Reporting frequency on 5 year basis.

**FEASIBILITY OF DEVELOPMENT:**

- Taxonomic expertise for weeds and cover crops at CLBRR and many Ag. Canada stations.

- Sampling expertise available at Agriculture Canada (CLBRR and Research Stations);

- Indicator can be developed in Short to Medium Term.

## POTENTIAL WILDLIFE HABITAT INDICATORS

1. Habitat Availability
2. Habitat Quality
3. Habitat Fragmentation
4. Habitat Restoration
5. Wildlife Species at Risk
6. Wildlife Population

**APPENDIX 7.4-1: HABITAT AVAILABILITY INDICATOR: QUANTITY AND TREND**

**Rationale and Policy Relevance.** The environment in which an animal lives and depends on is called habitat. The amount of habitat available to wildlife species in Canada has been shrinking due to land use conversion. The rationale for developing a composite habitat availability indicator is to determine the amount of grasslands, wetlands, and woodlands remaining; track changes in the amount of the various habitat types and determine the size classes or areal extent of existing habitats. The indicator reflects the overall condition of the environment and addresses the policy question: Is the quantity of wildlife habitat in the agricultural area of Canada being maintained (increasing or decreasing)?" The policy objective for this indicator would be to maintain or increase the amount of wildlife habitat in agricultural landscapes.

**LINKAGE WITH OTHER ISSUES:** Some environmental indicators address more than one environmental sustainability issue or policy question. The Habitat Availability Indicator has linkage with the soil resource issue (eg. Land alienation from agriculture or stock of agricultural land) and the water quantity issue (eg. percent of agricultural land with subsurface drainage). Since habitat loss causes loss of biodiversity this availability indicator is also linked to the issue of genetic resources.

**REPORTED PARAMETERS AND MEASUREMENT UNITS.** In order to quantify the availability of habitat we need to know where the habitat is and how much is left. For example, wetlands cover about 14 percent of Canada's surface area or 127 million $km^2$ yet wetland loss estimates are placed at 70 percent for southern Ontario and 40 percent for the Prairies; and 80 percent in the Fraser River Delta of British Columbia. If possible the major habitat types should be categorized by SIZE CLASSES (eg. $\leq$ 100 hectares, or $\geq$ 1000 ha). The extent of habitat change can be reported as a percentage loss or gain of existing habitat or in total area lost or gained. For example, in Alberta, an estimated 0.5 percent of wetlands disappear annually due to agricultural drainage (Alberta Water Resources Commission 1990).

**POTENTIAL SPATIAL SCALE(S).** The quantification of area and linear habitat features is feasible through the use of satellite imagery, aerial photos and sub-sampling of representative habitats in different regions (ecosystems). At present most habitat availability data has been collected on a provincial basis although wetland data bases apparently exist on a regional (prairie) scale. We suggest that the appropriate Spatial Scale for this indicator is both regional and national. Environment Canada's work to develop a framework for identifying indicators appropriate to Canada's Ecozones is underway and a welcome step towards adopting an Ecosystem approach.

**PROPOSED TEMPORAL SCALE.** Various censuses all databases are available leg. A catalogue of Ontario agro-ecosystems database). Wherever possible historical trends should be quantified. Apparently some databases (such as number of cultivated acres by province) are available annually. We suggest that a maximum reporting time be every five years with some regional/provincial habitat indicators available annually.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS.** Data to develop a habitat availability indicator should be available presently on a regional basis.
Development of an overall national indicator should be possible medium term (2-3 years) depending on resource commitment. Interagency cooperation with Environment Canada , Ducks Unlimited, NAWMP, Wildlife Habitat Canada, and the provinces is recommended

**APPENDIX 7.4-2: HABITAT QUALITY INDICATOR**

**RATIONALE AND POLICY RELEVANCE.** Degradation of the quality of wildlife habitat by agricultural practices, directly or indirectly, results in habitat loss which is not reflected by simple land use conversions (Indicator #1). Wildlife habitat can be degraded by the invasion of exotic plant and animal species, by livestock grazing and trampling, and by contamination with pollutants from agricultural sources. A key issue here is the loss/degradation of complementary habitat types. The best example is the loss of habitat around wetland margins. Clearing and cultivation to the edge of wetlands has eliminated nesting habitat for many wetland species as well as reduced the permanency of these waterbodies.

This habitat indicator addresses the policy question: Is the quality of wildlife habitat being maintained (increasing or decreasing)? The policy objective for this indicator would be to maintain or increase the quality of wildlife habitat in agricultural landscapes.

**LINKAGE WITH OTHER ISSUES:** The habitat quality indicator is linked to the genetic diversity issue, because the invasion of exotic species often results in a decrease in genetic diversity. It is also linked to the surface and groundwater quality issue.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:**

1. The amount (ha/sq km) or percentage of each habitat type invaded by exotic species, e.g. the percentage of remaining wetland invade by the weed purple loosestrife. Exotic species would be limited to those known to increase rapidly and

crowd out native forms of wildlife.

2. The amount (ha/sq km) or percentage of each habitat type physically degraded by livestock encroachment.

3. The amount (ha/sq km) or percentage of each habitat type degraded by agricultural pollutants.

**PROPOSED SPATIAL SCALE:** The proposed spatial scale for reporting the habitat quality indicator should be regional, because the habitat types and reported parameters will not be consistent from region to region. However, the information can then be summarized at the national scale for senior policy makers.

**PROPOSED TEMPORAL SCALE:** The habitat quality indicator should be reported every three years for degradation due to livestock, encroachment, and pollutants. The invasion of exotic species could be tracked annually, because some of these species spread very quickly.

**FEASIBILITY OF DEVELOPMENT:** Inter-agency cooperation is essential for the development of the habitat quality indicator (e.g. Environment Canada (DOE), provincial ministries of natural resources, conservation authorities). This indicator could be developed in the medium term (2-3 years) although much work needs to be done in the areas of exotic species and livestock impact on habitat quality.

## APPENDIX 7.4-3: HABITAT FRAGMENTATION INDICATOR

**Rationale and Policy Relevance.** The amount of habitat in Canada is not only shrinking, but parcels or patches of habitat are becoming increasingly fragmented. The gross total area of habitat is not a reliable guide to its quality or availability, which depend on the size and dispersion (fragmentation) of the habitat patches as much as on their cumulative area. Landscape attributes such as patch size distribution, patchiness, richness, dominance, fractal dimensions, contagion and amount/frequency of edge need to be factored in to develop this indicator. There has been little published research on fragmentation to date but the concept of this indicator is exciting because it represents an opportunity to move forward beyond the more "traditional" indicators used to date. The concept also has merit in terms of targeting programming which would join fragmented habitat patches in an agricultural landscape.

This indicator would address policy questions relating to maintenance of habitat quality as well as sustainability of wildlife populations in the agricultural landscapes.

**LINKAGE WITH OTHER ISSUES:** The Habitat Fragmentation indicator has particular linkage with the Genetic Resources Issue as well as Air and Climate, Surface Water Quality/Quantity and Pollution.

**Reported Parameters and Measurement Units.** Limited data available. Could be reported as species diversity (number of species) by patch size or number/size of patches per agroecosystem or map/sheet.

**Potential Spatial Scale.** The proposed spatial scale for reporting the habitat Fragmentation Indicator should be regional or by ecosystem. The regional information could be summarized at the national scale as data becomes available.

**Proposed Temporal Scale.** This indicator will not be available until developed. The reporting frequency will not likely be shorter than five years per land area analyzed. As satellite and Geographical Information System (GIS) technology improve and become less expensive, frequency of reporting could become annual.

**Feasibility of Development and Next Steps.** Interagency cooperation is recommended for the development of this indicator. If research shows fragmentation to be very important to wildlife and biodiversity, regional indicators could likely be developed in the 3-5 year range.

## APPENDIX 7.4-4: HABITAT RESTORATION INDICATOR

**RATIONALE AND POLICY RELEVANCE:** Some agroecosystems in Canada have been so modified from their original state, that only one percent or less of the original native vegetation remains on the landscape. However, recent policy and program developments in the agri-food and conservation sectors are resulting in soil conservation practices, wetland restoration and habitat enhancement Conservation agencies are monitoring and tallying these environmental enhancements.

For example, the 1991 Statistics Canada Census of Agriculture reports 65,186 km of shelterbelts/windbreaks planted in the four western provinces. Duck Unlimited Canada reports 55,000 ha enhanced for wildlife production in 1992. The Alberta NAWMP centre reports 38,062-acres of uplands and 9,604 wetland acres enhanced during 1992-93. And Agriculture Canada has sponsored the return of 1.29 million acres of marginal agricultural land to permanent cover. Wildlife Habitat Canada supports a two-pronged approach to conservation of habitat - a "protection strategy" and a "conservation strategy" which includes restoration and enhancement of the great variety of wildlife habitats across Canada. Their goal for agricultural landscapes is "to conserve, through partnerships, the diversity of wildlife habitats within Canada's agricultural landscapes."

It becomes apparent that these measurements of conservation effort and success are environmental indicators. Each Sector's tally could be rolled into a National Restored or Enhanced Habitat Indicator. Of course, the quality of these restored habitats is an obvious concern. Single row shelterbelts where the herbaceous vegetation is controlled with herbicides may be sufficient for wind erosion control but are of little benefit (or perhaps trap) wildlife. Wetlands restored exclusively for ducks may be of little significance for other wildlife species and very poor in plant and insect diversity. Monospecies forest plantations benefit only a few wildlife species. It could also be suggested that restored and enhanced habitats be tallied under the Habitat Availability Indicator.

This indicator would address policy questions concerning both the quantity and quality of habitat in agricultural Canada.

**LINKAGE WITH OTHER ISSUES:** This indicator has particular linkage with the Genetic Resources, Water Quantity, Soil Resources and Surface Water Quality issues.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** This indicator is currently reported on a sectoral basis. Examples include kilometres of shelterbelt planted, hectares of uplands and wetlands secured, enhanced and managed and dollars spent to accomplish these habitat ventures. This indicator could be measured and reported in hectares per habitat type or per agroecosystem.

**POTENTIAL SPATIAL SCALE:** The Restoration Indicator is currently reported at provincial scales with some agencies reporting national accomplishments. It could be reported at both regional and national scales.

**PROPOSED TEMPORAL SCALE:** The temporal scale could be yearly. Census of Agriculture data will only be available on a five year basis.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** A composite Restoration Indicator could be developed in the short to medium term (1-3 years). Conservation agencies will likely continue to report habitat restoration accomplishment on a yearly basis. Cooperation from all involved land use and habitat agencies is required to develop an overall composite indicator.

## APPENDIX 7.4-5: WILDLIFE SPECIES AT RISK INDICATOR

**RATIONALE AND POLICY RELEVANCE:** This indicate would provide a measure of the loss of biodiversity in Canada. Some agriculture practices may be contributing to endangerment of particular wildlife species. Since species loss/endangerment is usually directly attributable to habitat loss, this indicator addresses the policy question "Are wildlife populations in the agricultural regions being maintained."

**LINKAGE WITH OTHER ISSUES:** This indicator has particular linkage with Genetic Resources (maintenance of biodiversity); Water Quality; Soil Quality; Agricultural Inputs (pesticides); and Climate Change.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** The Species at Risk Indicator is reported as the percentage of wildlife species at risk in the categories of marine mammals, birds, terrestrial mammals, reptiles, amphibians, fish and native plants. Eventually invertebrates should also be included to reflect their contribution to biodiversity. Delisting of species is an indicator of a positive trend in this category.

The indicator presents the proportion of wildlife species identified as endangered, threatened or vulnerable as reported by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

**POTENTIAL SPATIAL SCALE:** The Species at Risk Indicator can be reported nationally. e.g. 15 percent Terrestrial mammals in Canada are at risk or regionally. e.g. 20 percent of all Canada's vertebrates "at risk" occur in the Canadian prairies, which occupy only 5% of the land area.

**POTENTIAL TEMPORAL SCALE: Annual** (Since COSEWIC officially lists endangered, threatened and vulnerable species annually)

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** Biological Diversity is under the most pressure in the highly disturbed habitats of southern Canada, which are impacted by agricultural land use conversion and urban uses and in the Arctic where less species diversity makes any change in the number of species more dramatic. Present knowledge of all biological resources is incomplete, particularly for insects. As the knowledge base increases the species at risk indicator may become more widely used. (The COSEWIC list provides information only on species reported on.)

This indicator is presently available. Agriculture and Agri-Food Canada must decide if it has policy relevance for the Agri-Food sector.

## APPENDIX 7.4-6: WILDLIFE POPULATION INDICATOR

**RATIONALE AND POLICY RELEVANCE:** Population levels (declining/increasing) are available for a variety of wildlife species, game and non game. The rationale for using/developing this indicator is that changes in populations of an individual wildlife species often reflect trends in available habitat for that species. For example, the 1993 Waterfowl Survey for southern Saskatchewan indicates the breeding Mallard population was 52 percent below the long-term mean and the Northern Pintail population was 83 percent below the long-term mean. These trends in population mirror trends in both the availability and quality of wetland habitat. One application of this indicator is to monitor the change in the number of species when agricultural activities commence on previously undisturbed land.

However, as indicated in the report caution must be observed in the use and interpretation of population indicators. Migratory species and species which are hunted for recreation are influenced by factors in other countries which may be both agricultural or non-agricultural in nature. Also some population indicators are more directly in the jurisdiction of and are being reported by other agencies such as the Canadian Wildlife Service (CWS). From the agricultural sector viewpoint, there is a more direct linkage between the agricultural landscape (and how it is managed) and wildlife habitat.

In the policy context, it is suggested that the Wildlife Population Indicator addresses the policy question: Are wildlife populations in the agricultural regions being maintained (sustained)?

**LINKAGE WITH OTHER ISSUES:** The Wildlife Population Indicator has particular linkage with Soil Resources, Surface Water Quality, Water Quantity, Air and Climate, Pollution and Genetic Resource Issues.

**REPORTED PARAMETER(S) AND MEASUREMENT UNITS:** The suggested Population Indicator is currently reported as Breeding population (millions of ducks) versus year. The indicator is also reported as the proportion of ducks (in percent) below the previous 10 year mean and between the current year and the long-term (1955 to current year) average.

**POTENTIAL SPATIAL SCALE:** The proposed spatial scale for the Wildlife Population Indicator is Regional. The transects and strata for the principal areas of waterfowl breeding population surveys are designed within provincial/state boundaries. In addition, some U.S. states conduct independent annual waterfowl surveys.

**PROPOSED TEMPORAL SCALE:** Trends in Duck Breeding Populations are currently documented on an annual basis by the U.S. Fish and Wildlife Service in cooperation with CWS and the provinces.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** Relatively long-term data for this indicator (1955 to present) is currently available. Inter-agency cooperation is required to document current land use and land use change and integrate this habitat data with the annual population surveys. This would make the indicator more useable in an agro-ecological context. With the advent of Geographic Information Systems (GIS) this integration should be feasible medium to long-term (3-5 years).

## POTENTIAL AIR & CLIMATE INDICATORS

1. Crop Production Carbon Balance
2. Methane Emissions from Domestic Ruminants
3. Relative Use of Nitrous Oxide Emitting Commercial Nitrogen Fertilizers
4. Greenhouse Gas Emissions from Animal Wastes under Typical Storage Conditions
5. Changes in the Agricultural Climate
6. Crop Water Use Efficiency

## APPENDIX 7.5-1: CROP PRODUCTION, CARBON BALANCE

### RATIONALE AND POLICY RELEVANCE:

An agricultural carbon balance, similar to that of Forestry Canada, responds to the first policy question. Whether agriculture is a net source or sink of $CO_2$, can agricultural emissions be reduced, or can the sector's role as a sink be enhanced, are all questions to be addressed in meeting Canada's commitment to reduce greenhouse gas emissions to 1990 levels by 2000.

The proposed carbon balance would be based solely on $CO_2$ exchange, leaving the $CH_4$ and $N_2O$ sources and/or emission rates as separate indicators. Because $CH_4$ and $N_2O$ are so much more potent as greenhouse gases than $CO_2$, a complete balance would be very sensitive to the conversion factors used (carbon equivalents).

Only photosynthetic carbon, involving physiological activities, would be tracked. Accumulation of plant dry matter is a result of the net $CO_2$ exchange rate between the crop and the atmosphere. Progress towards a complete carbon balance, taking into account all forms of carbon and the influence of all farming activities, rather than just the field or crop production processes, must result from coordination with the other environmental indicator issues.

A simple field level carbon balance is conceptualized as:

| | | | | |
|---|---|---|---|---|
| Net carbon balance | = | Crop biomass change | + | Soil carbon storage |

Crop biomass = (photosynthesis ) - (respiration +)
change + manure harvest + grazing
+ soil microbes + oxidation

The carbon balance would require intensive scientific development and calibration to sort out the $CO_2$ fluxes within the soil-plant-atmosphere system. Following development, extensive ongoing yearly measurements may be needed to operate the balance.

### LINKAGE WITH OTHER ISSUES:

Since soil carbon is a major component of the field carbon balance and is directly related to soil organic matter, there is a strong link between the carbon balance and the organic matter content of soil which is an indicator of soil management and quality. Soil carbon change over time is a residual of the field carbon balance.

The current project in CLBRR to map soil carbon across Canada makes it a potential stand-alone indicator of whether crop production is a sink or a source of carbon. Repeating the national mapping exercise in five years, however, will be just as expensive as the original map. The inability to track year to year changes of soil carbon restricts soil carbon as a practical indicator unless the soil carbon fluxes could be simulated.

### REPORTED PARAMETERS AND MEASUREMENT UNITS:

Units will be: t $CO_2$ /year integrated up from the field values of mg $m^{-2}$ $s^{-1}$ using total annual crop areas across Canada.

### POTENTIAL SPATIAL SCALES:

Integrated national and regional $CO_2$ emissions from fields should be possible if a carbon balance (field level) simulation model can be developed which is weather based.

### PROPOSED TEMPORAL SCALE:

Annual or growing season values are possible if a carbon balance (field level) weather based simulation model can be developed. Net $CO_2$ emissions from fields/annual crops can be represented in multi-decade or multi-year time series, as well, depending on the success in developing a weather based simulation model.

### FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:

The indicator would incorporate a simulation model of the carbon balance where the various fluxes would be scientifically parameterized. A recent research paper from CLBRR demonstrates this approach for the net canopy $CO_2$ exchanges of a soybean crop. The model would require balancing the following $CO_2$ fluxes:

- net crop $CO_2$ exchange rates ($F_{c,c}$)
- soil surface $CO_2$ flux ($F_{c,s}$)
- vertical $CO_2$ flux above the crop ($F_{c, a}$)

Direct measurement of $F_{c,c}$ is not possible since the vertical $CO_2$ flux measurements above the crop canopy also include the $CO_2$ produced by the microbial activity and oxidation of soil organic matter ($F_{c,s}$). $F_{c,c}$ must be estimated from the difference of $F_{c,s}$ and $F_{c,a}$ minus the respiration rates of the roots. $F_{c,s}$ has been successfully measured and $F_{c,a}$ is measurable using the eddy-correlation technique. $F_{c,c}$ is a function of the gross crop photosynthesis ($P_{g,c}$) and the respiration rates of the roots ($R_f$) and above ground crop tissue ($R_{ag}$). The fraction of $F_{c,s}$ originating from microbial oxidation of soil organic matter is approximately 15% of daily canopy net photosynthesis ($P_{n,c}$).

## APPENDIX 7.5-2: METHANE EMISSIONS FROM DOMESTIC RUMINANTS

**RATIONALE AND POLICY RELEVANCE:** Worldwide agricultural activities may be contributing 45% of the methane going into the atmosphere. In fairness to Canadian agriculture, rice paddies in the tropics probably emit the largest single portion of this methane. However, up to 30% of the agricultural $CH_4$ is controllable and therefore a target for reduction strategies. If the world agricultural community is called upon to reduce methane emissions, then all countries, not just the rice producers in the tropics, will be pressured to find ways of reducing methane emissions. Ruminant sources will then receive considerable attention and quantitative answers will be needed.

Ruminant methane is a by-product of the digestive microbial breakdown of carbohydrates and represents a loss in feed conversion efficiency of approximately 6 to 8% of gross energy intake. Methane production is affected by animal type (dairy, beef, sheep, etc.) and age, metabolic live weight, milk production, diet (quality and quantity), and enclosure (barn, feedlot, pasture etc). Some of these factors may be used to describe and predict methane emissions from ruminants. By modelling methane fluxes from cattle under typical management practices, it should be possible to estimate emissions from domestic ruminants in a range of conditions across Canada.

**LINKAGE WITH OTHER ISSUES:** The size of animal population will influence the quantity of animal wastes which may a consideration in soil management practices. Any change in the animal diet may affect the manure composition and the components of that diet may reflect farm inputs.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** Units will be t $CH_4$ /year for all Canadian domestic ruminants.

**POTENTIAL SPATIAL SCALES:** Methane productions reflects regional differences since most dairy cattle are in the eastern regions while beef cattle are mainly in the western regions. Available livestock population records would allow scientifically determined emission rates per animal to be extrapolated nationally.

**PROPOSED TEMPORAL SCALE:** Methane emissions over a full year should be determined. Estimates should be updated for animal type and population changes, or if different management practices are used.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** A research project aiming at the continuous measurement of methane and carbon dioxide produced by a typical dairy cow in a barn, under standard management practices is being carried out at CFAR. Methane emissions from new diets will also be tested.

It will take several years to collect the information on methane emissions for typical management practices: milk production, with or without grazing, beef production in feedlot, etc. Barn emission measurements could be extrapolated to other locations Methane emissions from grazing cattle may be influenced by climate and therefore would require experiments in several regions. The experimental data will calibrate predictive models of the impact of management practices on methane emissions. These models could be used to calculate yearly total methane emissions from domestic ruminants.

## APPENDIX 7.5-3: RELATIVE USE OF NITROUS OXIDE EMITTING COMMERCIAL NITROGEN FERTILIZERS

**RATIONALE AND POLICY RELEVANCE:** Atmospheric nitrous oxide is 1000 times lower than atmospheric carbon dioxide. But because the potency of $N_2O$ as a greenhouse gas is 150 times greater than $CO_2$, and because the atmospheric concentration of $N_2O$ is increasing at 0.25% a year, $N_2O$ is a growing concern. Nitrous oxide from all sources is thought to be contributing about 6% of the greenhouse effect on global warming.

While all commercial nitrogen fertilizers emit $N_2O$, certain types of nitrogen fertilizers emit more than other types. A shift away from anhydrous ammonia in fertilizer use may significantly reduce agricultural greenhouse gas emissions. Therefore the type of fertilizers used could be a useful indicator.

Although the scientific understanding is at an early stage, the anhydrous ammonia based nitrogen fertilizers seem to emit $N_2O$ at a much higher rate than other forms of fertilizer, while nitrate based fertilizers are much less prone to $N_2O$ emissions (or volatile) than ammonia based fertilizers. At a 5% loss rate, compared to 0.17% for ammonia based and as low as 0.04% for nitrate based fertilizers, anhydrous ammonia based fertilizers are the most volatile form of fertilizers Approximately 90% of the nitrogen fertilizers are in ammonia form. While anhydrous forms are about 29% of total use, they contribute 90% of the $N_2O$ emissions.

**LINKAGE WITH OTHER ISSUES:** There may be overlap with farm inputs indicators, since this source of $N_2O$ emissions is based on rates of fertilizer use. There may also be overlap with water quality since more reliance on nitrate forms would increase the potential for nitrates leaching into groundwater.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** Since this indicator is not intended to reflect total nitrogen fertilizer use, a relative representation of $N_2O$ emitting fertilizer is more appropriate than actual amounts used. The proposed indicator would be the ratio of the anhydrous ammonia and ammonia based fertilizers to non-ammonia based fertilizers. The relative value was chosen because $N_2O$ emissions from fertilizer use are difficult to quantify.

**POTENTIAL SPATIAL SCALES:** The availability of nitrogen fertilizer use data should allow reporting of fertilizer type usage to be aggregated regionally or nationally.

**PROPOSED TEMPORAL SCALE:** Annual values can be represented in multi-year time series if historical data can be found or proxied. An annual value would represent the total growing season use.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** More research needs to be done on these differences, since continued downstream $N_2O$ emissions may be significant and are difficult to measure. However, because these preliminary emission or volatility data show that anhydrous ammonia based fertilizers are orders of magnitude higher than for nitrate forms, the potential for designating the type of nitrogen fertilizer used as an indicator is very good. Furthermore, it seems that cutting down the use of anhydrous ammonia would be an effective way to reduce $N_2O$ emissions.

## APPENDIX 7.5-4: GREENHOUSE GAS EMISSIONS FROM ANIMAL WASTES UNDER TYPICAL STORAGE CONDITIONS

**RATIONALE AND POLICY RELEVANCE:** With a worldwide estimate of 45% of the atmospheric methane coming from agriculture and up to 30% of the agricultural $CH_4$ being controllable, all possible methane sources in the sector are a target for reduction strategies. Animal manure is produced in significant quantities in Canada, is increasingly recognized as a valuable resource and is being subjected to increasingly intense management. Given Canada's commitment to reduce emissions of all greenhouse gases to 1990 levels by the year 2000, it is paramount that we promote manure management practices that decrease, rather than increase, greenhouse gas emissions.

Methane is produced during anaerobic decay of the organic material in animal waste. Production of volatile acids, precursors of methane emissions, is dependent on the amount and ratio of biodegradable carbon. The end products of the complete anaerobic process are methane gas, carbon dioxide gas and other trace gases, including some possible $N_2O$.

Greenhouse gas (GHG) production is affected by animal types, waste composition, storage conditions (% oxygen), volume and duration, water content and temperature. $N_2O$ may be produced during both anaerobic (denitrification) and aerobic (nitrification) conditions. These factors may help to quantify GHG emissions.

Animal numbers and type could be used to estimate manure production. The manure management conditions (% oxygen, water added, litter, storage system capacity and duration) used on Canadian farms should be characterized. By modelling GHG fluxes from typical manure type and storage conditions, it should be possible to estimate GHG emissions from animal wastes.

**LINKAGE WITH OTHER ISSUES:** The storage conditions of animal wastes influence its pollution potential as well as its fertility level which reflects a need to augment manure spreading with the use of commercial fertilizer, an issue in the environmental effects of inputs. Since some commercial fertilizers also produce $N_2O$, a trade-off against manure management with respect $N_2O$ may also require investigation.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** Units for a given storage system will be g gas / kg manure over a storage period for $CH_4$, $CO_2$ and $N_2O$ emitted by manure expressed as $CO_2$ equivalents. $CO_2$ from manure may not be significant, however. Integration over total manure volume would give a total emissions for Canada.

**POTENTIAL SPATIAL SCALES:** The GHG emissions will be mainly related to the total volume of manure production in Canada which could be calculated from the total farm animal population. Because weather and management conditions affect emission rates, adjustments would be required to account for typical regional manure handling practices and climate.

**PROPOSED TEMPORAL SCALE:** Reporting would be for GHG emissions for the storage period which will need to be determined. Estimates should be updated annually to reflect animal type and population changes or different storage system developments and uses.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** The Air Quality group of CLBRR has quantified the fluxes of GHG emitted from animal manure in anaerobic lagoons, stockpiled and composted by the passive aeration method. CFAR will soon monitor the GHG emissions from a manure slurry tank. Indicator development will require several years of information on GHG emissions for typical storage systems and for manure of different animal types for typical regions in Canada. This experimental data will be used to calibrate a predictive model for manure handling whose output would provide the basis of an indicator for the total GHG emissions from stored manure.

Most GHG emissions from animal waste are based on determination of methane emission from digesters, since methane production using animal waste is becoming economically feasible for larger scale animal production operations. However, the production of greenhouse gases ($CO_2$, $CH_4$ and $N_2O$) under typical farm manure storage conditions is not adequately known. Information on how much methane producing anaerobic decay takes place before field application is also inadequate.

## APPENDIX 7.5-5: CHANGES IN THE AGRICULTURAL CLIMATE

**RATIONALE & POLICY RELEVANCE:** Long term changes in both average values and in variability of agroclimates can potentially reduce the sustainability and profitability of agricultural production in the long term. In the shorter term, seasonal climatic variability has impacts on crop production and on payouts of safety net programs such as crop insurance, as well as on their environmental impacts. Spatial variations in agroclimate affect agricultural productivity and profitability, as well. Better understanding of the agroclimate systems can improve management decisions by both government and the agricultural industry.

Neither of the above policy questions directly addresses societal responses to the long or short term climate related risks. A third policy question as to whether Canadian agriculture is becoming more or less vulnerable to weather risk should be considered. This question is complicated by changes in climate variability which may result from the greenhouse effect. Although no indicators of on-farm decision making response to these risks are proposed, indicators solely for climate variability changes are a useful starting point for understanding the vulnerability question.

**LINKAGE WITH OTHER ISSUES:** The linkage with environmental indicators for other issues will be that this set of agroclimatic information can help clarify trends in the other indicators by normalizing out weather based noise in the time series presentations. The data base used to calculate the agroclimatic indicators can be used to run a soil moisture simulation model of crop growing conditions and crop yields. For example, actual evapotranspiration accumulated over the growing season derived from simulated soil moisture relates well to yields. Soil moisture simulations underpin water supply/water quantity issues and soil quality issues where crop water use may be important in making extrapolations from crop yield data.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** There is no single variable which entirely describes the dynamics of the agroclimatic system. However, once a weather records data base and software have been put in place to generate one agrometeorological variable, other variables could be easily generated upon request. Therefore the approach taken for the agroclimatic indicator is to identify a major reporting variables while maintaining the ability to calculate a wider range of variables at short notice.

The choices favour simplicity, but still reflect the agroclimate rather than just climate. The principle choices are:

a) growing degree days (GDD) above a base temperature
b) precipitation (P) - potential evapotranspiration (PE)
c) diurnal temperature range (Tmax-Tmin)

GDD indicates the increased heat available for crop growth from global warming, P - PE indicates the moisture stress on crops and Tmax-Tmin indicates atmospheric humidity, since maximum temperature (Tmax) is reduced by cloud cover while the minimum temperature (Tmin) approximates the dew point. Some other options would include: frost free periods, winter cold units, average monthly temperature during spring (planting) and fall (harvesting), total hours of bright sunshine, seasonal precipitation, and days with precipitation.

The actual units reported would depend on the variable, but the normalized form (per cent of a long term average) which renders the variable dimensionless, is usually more useful.

**PROPOSED TEMPORAL SCALE:** Presentations would show annual values represented in multi-decade or multi-year time series with annual updates.

**POTENTIAL SPATIAL SCALES:** Time series charts could be prepared on a station basis, or aggregated locally, regionally or nationally by averaging weather station calculations. Maps could be used to compare current climate conditions to selected past periods.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** The basis of climate change indicators is to show change, if significant, and the direction of change. The ability to create a time series, that is acquiring historical data and assuring future availability of the same data, is fundamental to climate change indicators. The historical weather records maintained in edited computer readable format by CLBRR represent a sufficiently long data set at many weather stations, depending on the length of period required, to show trends in major agricultural areas.

The generalized indicator would take the form of a weather records data base from which time series or long term statistics (mean and variances etc) would be derived. From sequences of daily temperature and precipitation records over many years, a wide range of agroclimatic parameters could derived. Computer programs can be written which compute all of the above variables in a single run and generate statistical summaries of the selected time series. Building and maintaining such a data base would be very low cost.

## APPENDIX 7.5-6: WATER USE EFFICIENCY OF TYPICAL CANADIAN AGRICULTURAL CROPS

**RATIONALE AND POLICY RELEVANCE:** Increased atmospheric concentration of carbon dioxide ($CO_2$) will have a fertilization effect on plant photosynthesis and will increase water-use efficiency by changing the stomata) aperture. As a result, the amount of $CO_2$ fixed by plants per unit of water transpired (water-use efficiency) will increase. Increased water Use Efficiency (WUE) and enhanced $CO_2$ uptake during photosynthesis is a potentially beneficial effect of higher atmospheric $CO_2$.

The policy relevance of increased water Use Efficiency from climate change will become clearer as other policies related to adaptation and carbon sequestering take shape. It is presently quite clear, however, that impacts and suggested response strategies to impending climate change effects, such as drought and heat stress on crops, will have to be tempered by the gains expected from higher WUE. The wide range $CO_2$ relationships that will be affected justify WUE as a stand-alone indicator.

The degree to which WUE will increase is uncertain. Certain crops groups (the $C_3$ plants) should benefit more than others ($C_4$ plants). Environmental conditions (radiation, soil water content, air temperature, etc.) that are likely to change in the near future will also modify WUE. The rate of change of the WUE for typical Canadian agricultural crops represents an indicator of a very important impact of the changes in atmospheric chemistry on Canadian agriculture. Measurements under scientifically controlled conditions may be the only way to acquire the data.

**LINKAGE WITH OTHER ISSUES:** The changes in WUE may be a critical factor in estimating the net contribution of Canadian agriculture to atmospheric loading of greenhouse gases or in determining the role of the sector as a sink. The agricultural carbon balance (proposed above) should show significant sensitivity to this factor. WUE will also impact the effectiveness of water supply to crops, whether by irrigation or rain-fed cultivation, and will have a link with water quantity issues.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** Units will be in g $CO_2$ / g $H_2O$.

**POTENTIAL SPATIAL SCALES:** The spatial scale will be that of a field (approximately 10 ha). Since the proposed parameter is a dimensionless number, integration across all common field crops and regions could be done to give national as well as regional values.

**PROPOSED TEMPORAL SCALE:** WUE as an indicator can be reported every two or three years. Previous research carried out in Ottawa and elsewhere can provide data for the past 5 years and some scarce data are available from the early 1980's. Measurements of WUE can be made on different crops every year, the same crop being measured every three years.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** Carbon dioxide and water vapour exchanges between agricultural crops and the atmosphere have been measured at the scale of a field during the last five growing seasons in Ottawa by Agriculture Canada scientists (CLBRR, Air Quality group). Water-use efficiency can therefore be calculated for that period and serve as a reference for comparison with future measurements.

The environmental conditions under which WUE is determined are more relevant than the spatial scale of its measurements. Those conditions are canopy development (full or closed), whether soil moisture is limiting, plant growth stage (active vs dormant), optimum air temperature and dry soil surface.

There is practically no development efforts needed to implement WUE measurements as an environmental indicator. However, resources have to be committed to the purchase of additional instruments dedicated to the monitoring of targeted crops.

## POTENTIAL AGRICULTURAL INPUTS INDICATORS

1. Cultivated Area (cropped and summerfallow) Per Quantity Of Output and Value Of Production By Province

2. Energy Consumption by the Livestock Sector Under Confinement, Per Quantity Of Output And Value Of Production, By Province

3. Energy Consumption On-Farm, But Not In Confined Livestock Or Field Operations

4. Fertilizer Use Intensity

5. Composite Pesticide Management

6. Composite Pesticide Use

7. Composite Pesticide Risk

## APPENDIX 7.6-1: QUANTITIES OF FUEL USE (BY TYPE) FOR FIELD OPERATIONS PER CULTIVATED AREA, PER QUANTITY OF OUTPUT AND VALUE OF PRODUCT BY PROVINCE

**RATIONALE AND POLICY RELEVANCE:** This indicator is a measure of energy utilization in crop production, but is restricted to field operations. All forms of energy are included, i.e gasoline and diesel in farm tractors, electricity consumed by irrigation equipment, etc. This indicator will provide a measure of energy efficiency in crop production, and provide the statistical basis for related policy analysis.

**LINKAGES WITH OTHER ISSUES:** There are two issues that are linked to the consumption of petroleum products. One is motor vehicle emissions, which are a major source of air quality problems, particularly in some areas of Canada. The second is the contribution of these fuels to climate change or global warming.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** The quantities should be reported in units specific to the energy type, i.e litres of gasoline and diesel, kilowatt hours for electricity, $m^3$ for natural gas, etc. This information can also be specified in a common unit that is used conventionally by the energy industry, i.e. joules. The output units can be expressed in terms of quantity, eg. tonnes of wheat, and/or in terms of value, such as energy use per dollar of wheat production.

**POTENTIAL SPATIAL SCALE:** The data should be aggregated at the provincial level. Further breakdowns of the data would be useful, and depending on the methodology of data gathering may well be accommodated. This would include energy use/area by soil zones, or by type of crop.

**PROPOSED TEMPORAL SCALE:** Data should be gathered on an annual basis. However, further dis-aggregation that measures seasonal use of energy (i.e. planting or harvesting) would be useful in tracking any trends in energy use related to these activities.

**FEASIBILITY AND DEVELOPMENT OF NEXT STEPS:** There is little gathering of data on the energy quantities used by the agriculture sector. The Department of Natural Resources is investigating the possibility of establishing a Centre of Excellence for Agricultural End-Use in Saskatchewan. There presumably is Green Fund money available to fund this type of activity. Agriculture Canada should be in consultation with Natural Resources in this exercise, or may even wish to contribute funds in order to have some say in the process.

## APPENDIX 7.6-2: ENERGY CONSUMPTION BY THE LIVESTOCK SECTOR UNDER CONFINEMENT, PER QUANTITY OF OUTPUT AND VALUE OF PRODUCTION, BY PROVINCE

**RATIONALE AND POLICY RELEVANCE:** This indicator measures the amount of energy (by type) consumed specific to livestock operations. It is rather narrowly focused to the energy consumed in confined facilities, but does not apply to operations outside confinement.

**LINKAGES WITH OTHER ISSUES:** There are two issues that are linked to the consumption of petroleum products. One is motor vehicle emissions, which are a major source of air quality problems, particularly in some areas of Canada. The second is the contribution of these fuels to climate change or global warming.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** The quantities should be reported in units specific to the energy type, i.e litres of gasoline and diesel, kilowatt hours for electricity, $m^3$ for natural gas, etc. This information can also be specified in a common unit that is used conventionally by the energy industry, i.e. joules. The output units can be expressed in terms of quantity, eg. lbs of pork, and/or in terms of value, such as energy use per dollar of pork production.

**POTENTIAL SPATIAL SCALE:** The data should be aggregated at the provincial level, and by type of livestock operation., i.e. hog, cow-calf, dairy, etc. Further breakdowns of the data would be useful, i.e. energy consumption by farm size.

**PROPOSED TEMPORAL SCALE:** Data should be gathered on an annual basis, but can be further disaggregated to measure seasonal use, i.e. winter vs. summer energy consumption.

**FEASIBILITY AND DEVELOPMENT OF NEXT STEPS:** There is little gathering of data on the energy quantities used by the agriculture sector. The Department of Natural Resources is investigating the possibility of establishing a Centre of Excellence for Agricultural End-Use in Saskatchewan. There presumably is Green Fund money available to fund this type of activity. Agriculture Canada should be in consultation with Natural Resources in this exercise, or may even wish to contribute funds in order to have some say in the process.

## APPENDIX 7.6-3: ENERGY CONSUMPTION ON FARM, BUT NOT IN CONFINED LIVESTOCK OR FIELD OPERATIONS

**RATIONALE AND POLICY RELEVANCE:** This is a measure of all other energy usage on the farm, i.e other than direct on-field crop production, or confined livestock areas. This is a separate category since energy consuming activities may be common to both field and livestock (or other) operations.

**LINKAGES WITH OTHER ISSUES:** There are two issues that are linked to the consumption of petroleum products. One is motor vehicle emissions, which are a major source of air quality problems, particularly in some areas of Canada. The second is the contribution of these fuels to climate change or global warming.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** The quantities would be reported in units specific to the energy type, i.e litres for gasoline and diesel, kilowatt hours for electricity, $m^3$ for natural gas, etc. This information can also be specified in a common unit commonly used by the energy industry, i.e. joules.

**POTENTIAL SPATIAL SCALE:** The data should be aggregated at the provincial level. Further breakdowns of the data would be useful, such as home energy use, barn heating, etc.

**PROPOSED TEMPORAL SCALE:** Data should be gathered on an annual basis, but further disaggregation that measures seasonal use, i.e. winter versus summer consumption.

**FEASIBILITY AND DEVELOPMENT OF NEXT STEPS:** There is little gathering of data on the energy quantities used by the agriculture sector. The Department of Natural Resources is investigating the possibility of establishing a Centre of Excellence for Agricultural End-Use in Saskatchewan. There presumably is Green Fund money available to fund this type of activity. Agriculture Canada should be in consultation with Natural Resources in this exercise, or may even wish to contribute funds in order to have some say in the process.

## APPENDIX 7.6-4: FERTILIZER INTENSITY INDICATOR

**RATIONALE AND POLICY RELEVANCE:** The indicator proposes to measure changes in the amounts of actual nutrients from inorganic sources applied per unit area of cultivated land. The indicator attempts to isolate the environmental risks associated with inorganic fertilizer use relative to other factors, such as:

- plant breeding (more or less efficiency in nutrient uptake/conversion to yield);
- agronomic practices (e.g. replacing fertilizer nitrogen with nitrogen derived via crop rotations, animal manures; timing of fertilizer applications etc.) ; and
- technology (e.g. new products that replace or reduce the amounts of traditional fertilizers required for crop production).

Variability in growing season conditions will affect th reliability of this indicator.

This indicator is already in use at an international level and would be worthwhile in making comparisons with other countries.

**LINKAGES WITH OTHER ISSUES:** Fertilizer use intensity relates to the issues of soil management (maintaining soil productivity) and water quality (nutrient contamination of ground and surface waters). More or less intensive use may impact on either issue or both .

**REPORTABLE PARAMETERS AND MEASURABLE UNITS:** Changes in the kilograms (on a percentage basis) of nitrogen, phosphorus, potassium and other plant nutrients required per unit of cultivated land. Alternatively, it could be expressed in terms of kg. of applied nutrients per unit of production (eg. bushel of grain, cwt. of potatoes etc.) would be reported.

**POTENTIAL SPATIAL SCALE:** The indicator should be reported for specific groups of crop kinds (eg. grain and silage corn, oilseeds, grain legumes, small grains, potatoes etc.) for distinct production areas (eg. Prairies, Atlantic, southwestern Ontario etc.).

**PROPOSED TEMPORAL SCALE:** Year-to-year assessments may not show any discernable differences in use intensity. Reporting on a cycle in line with the Census of Agriculture (5 years) may be more useful and representative of real trends.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** This indicator is already reported at a gross, national scale annually which lends itself to comparisons internationally on a similar scale. A medium-term goal would be to fine tune the indicator on a more regional basis. Detailed yield and fertilizer use data is required in the development of other proposed indicators so if it can be secured, the data can be used to generate more than one indicator. Measuring changes attributable to plant breeding, technology and production practice alternatives will be more difficult to determine. A list of pertinent factors affecting use intensity for each group of crop kinds will have to be developed and related information needs identified.

## APPENDIX 7.6-5: COMPOSITE PESTICIDE MANAGEMENT INDICATOR

**RATIONALE AND POLICY RELEVANCE:** This indicator tracks the extent of adoption and non-compliance by farmers of selected management practices for pesticides. The policy goal is to promote environmentally sound pesticide management.

**LINKAGE WITH OTHER ISSUES:** Relevant to both the agricultural soil resources issue and the surface and groundwater quality issue.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:**

- % of licensed pesticide applicators or % of pesticides applied by a licensed applicator.
- Acreage covered by IPM programs (Integrated Pest Management).
- Number or % of farmers who spray by schedule (i.e. according to provincial weed control recommendations)
- Percent of pesticide containers recycled.
- Number of violations of prescribed pesticide use practices relative to the person-year resources going into monitoring.

**SPATIAL SCALE:** Several options. By watershed, province, by ecozone or agro-ecological resource area or nationally.

**TEMPORAL SCALE:** Indicator could be reported to coincide with the Census of Agriculture. This would depend on the availability of the data. Some start in the mid 1980's. Container data starts in 1990. "Spraying by schedule" data will not be collected in 1996. The data does not have to be reported annually.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** This will depend in large part on the availability and condition of data. Some data could be compiled at the provincial level over the short term. Spray by schedule data would have to be asked of farmers for the first time on the 2001 Census of Agriculture - it is the only management indicator requiring longer term development work.

## APPENDIX 7.6-6: COMPOSITE PESTICIDE USE INDICATOR

**RATIONALE AND POLICY RELEVANCE:** This indicator tracks the total amount of pesticides used in primary agriculture in Canada. Domestic and residential pesticide use would not be tracked. Parameters measured include the tonnes of active ingredient (ai) used in Canada, the total farmland area sprayed (ha), the percent of farmland area sprayed, and the intensity of pesticide use (kg ai/ha).

These indicators do not consider the relative risk of individual products but groups all products together. The general assumption is that less pesticide use means reduced potential environmental risk. If total pesticide use and percent of farmland sprayed is reduced through time, then we would assume that dependency on pesticides is decreasing and there is less environmental risk. Some jurisdictions have set pesticide use-reduction targets as a policy goal.

Total weight of pesticides used is not a perfect indicator on its own because currently there is a trend of using concentrated products which require low doses. Tracking the percent of farmland sprayed would be a more relevant indicator of pesticide use in agriculture since application rates are not considered.

**LINKAGES WITH OTHER ISSUES:** Other issues that are linked to pesticide use include soil and water contamination, human health, and wildlife. If pesticide use is reduced, then we would assume that the risk of environmental contamination would also be reduced.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** One of the measurements will be to report pesticide usage in tonnes of active ingredient per year. This would be reported as a total for all pesticides, but could also be grouped for herbicides, insecticides and fungicides. Product specific information would not be available because it is confidential. Estimates on total pesticide use are available from the Environment Canada/Agriculture Canada Survey of Registrants.

Total farmland area and total farmland area sprayed would be reported in hectares. This data is available from Census of Agriculture data. Based on these estimates, the percent of farmland sprayed can be calculated.

The pesticide intensity can also be calculated by dividing total tonnage of pesticides by total area of farmland sprayed (i.e. kg ai/ha). This calculation would ignore the fact that the same acre of land is treated with a number of products and multiple applications per year.

**POTENTIAL SPATIAL SCALE:** Estimates on tonnage of pesticides used are available on a national scale. Some provinces also track tonnage of pesticides used. Information on farmland area and farmland area sprayed should be available by province. Further breakdowns would be useful, such as agricultural sector, soil zone, critical area, etc.

**PROPOSED TEMPORAL SCALE:** Parts of the indicator could be reported annually and/or following completion of the Census of Agriculture. Data on tonnage of pesticides used is gathered on an annual basis, but there is a two year lag in availability of the results. Data on the tonnage of pesticides used goes back to the mid 1980's, but the older lists do not include all products. Farmland area and farmland area sprayed are collected by the Census of

Agriculture.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** Most information needed to construct the Composite Pesticide Use Indicator is in place and is accessible. Calculations on the percent of farm land sprayed and the intensity (kg ai/ha) can be performed from the existing data sources. Some of the older data on total tonnage will need to be adjusted because not all products were included in earlier surveys.

## APPENDIX 7.6-7: COMPOSITE PESTICIDE RISK INDICATOR

Indicator tracks pesticide use based on trends in use of various classes of active ingredients (based on potential environmental risk).

**RATIONALE AND POLICY INDICATOR:** A Composite Pesticide Risk Indicator would combine trends in pesticide use with characteristics of the pesticides related to environmental risk (e.g. toxicity, persistence, etc.). Pesticides would be classed according to their potential environmental hazard. The tonnage for each class would be estimated and the percent of farmland sprayed with each class calculated. With such a system, trends for each class of pesticide would be tracked.

**LINKAGES WITH OTHER ISSUES:** Issues that are linked to the Pesticide Risk Indicator include soil and water contamination, human health and wildlife.

**REPORTED PARAMETERS AND MEASUREMENT UNITS:** The total annual tonnage (active ingredient basis) for each class of pesticide could be calculated annually. The percent of farmland sprayed with each class could also be determined. Data collected for the Pesticide Use Indicator would be used to estimate tonnage used and percent of farmland sprayed.

**POTENTIAL SPATIAL SCALE:** Estimates on tonnage of pesticides used in each hazard class should be determined on a national scale and if possible, be broken down by province, agricultural sector, critical area, etc.

**PROPOSED TEMPORAL SCALE:** Data on tonnage for each class would be gathered on an annual basis.

**FEASIBILITY AND DEVELOPMENT OF NEXT STEPS:** The challenge in developing the Composite Pesticide Risk Indicator will be to develop and environmental risk classification system for pesticides in Canada. An example of a classification system has been recently developed at Cornell University ("A Method To Measure The Environmental Impact Of Pesticides"). Such a system or a comparable Canadian system could be agreed on by federal departments and others (i.e. industry, interest groups, etc.). As well environmental databases for some older products are incomplete.

## POTENTIAL WATER QUALITY INDICATORS

1. Pesticide Contamination
2. Plant Nutrient Contamination
3. Agricultural By-Products
4. Solids Loading

## APPENDIX 7.7-1: PESTICIDE CONTAMINATION INDICATOR

**RATIONAL & POLICY RELEVANCE:** Pesticides play a key role in modern agricultural production. Contamination problems relating to occurrence of some pesticides in water (and soil) are attributed to the degradation characteristics of the chemical and/or to the influences of particular soil and weather conditions and cultural practices. Concern regarding pesticide residues in water has focused primarily on human health rather than the broader spectrum of humans, livestock, wildlife and the environment in general.

Significant advances in detection capability have precipitated and encouraged the widespread identification of pesticides and metabolites in surface and ground water. However, concerns regarding detectable residue levels (ppb, ppt) are not necessarily accurate or justified without an improved and more holistic understanding of the impact on the natural resources, general health and long term safety implications.

The development of meaningful indicators is essential to support the continued adoption of agricultural management practices which will ensure a safe and productive agricultural sector which demonstrates the sector's performance in relation to established standards.

**LINKAGES WITH OTHER ISSUES:** Use of agricultural pesticides can result in unacceptable impacts on the quality of water, soil and air. Indicators would also relate to soil and air quality issues.

**REPORTING PARAMETERS AND MEASUREMENT UNITS:** National and international tolerance levels are established in ppm. Comparisons are made against existing standards/guidelines and the significance of levels above accepted thresholds.

**PROPOSED SPACIAL SCALE:** Analysis should be done on a scale which will reflect the major agricultural production activity as well as the significant factors of risk such as soil profile, persistence, toxicity etc. The scale of assessment could be national, regional, sub-regional or watershed.

**TEMPORAL SCALE:** In most cases, for both a particular area or problem, a seasonal as well as a yearly scale would be most meaningful.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEP:** A priority list of pesticides and areas in Canada vulnerable to surface ground water contamination must be developed to reduce analytical costs to an acceptable level.

Develop a performance indicator based on data developed in collaboration with appropriate federal and provincial government agencies and universities.

## APPENDIX 7.7-2: PLANT NUTRIENT CONTAMINATION INDICATOR

**RATIONALE AND POLICY RELEVANCE:** Today's agricultural industry relies on improved soil fertility for producing high quality food for the public. Incorrect application rates and timing of these nutrients may cause nutrient imbalances that could be detrimental to both the soil and water. Contamination of the water may be from a non-point or point source; the source of contamination may be from inorganic fertilizers, soil organic matter, animal or human wastes (i.e. septic systems), livestock manures or from geologic sources. Soil nitrogen is very dynamic in nature compared to phosphorous, therefore a single value per unit of time does not accurately reflect the effect of nitrogen in surface water particularly.

Nitrogen and phosphorus are essential plant nutrients and elevated concentrations in surface water will stimulate aquatic growth changing habitat, affecting species diversity, and eventually resulting in eutrophication. A nutrient contamination indicator which reports the sectors performance in relation to established guidelines is necessary to minimize environmental degradation.

**LINKAGE WITH OTHER ISSUES:** Water quality problems are normally a result of agricultural management practices. Thus the necessary link to land and soil resource and agricultural inputs issues.

**REPORTING PARAMETERS AND MEASUREMENT UNITS:** Negative or positive trends (seasonally and yearly time series analyses) of nutrient levels, in water would be reported in comparison to established water quality objectives.

**POTENTIAL SPATIAL SCALE:** Analysis should be done on a watershed\aquifer scale that may rage from 1:50000 to 1:250000. For detailed investigations 1:10000 to 1:20000 could be used.

**PROPOSED TEMPORAL SCALE:** For the more dynamic nutrients like nitrogen, a seasonal accumulated value is more meaningful for a particular area, problem or scale than a single annual value. A temporal scale for other less dynamic nutrients may be on a 2 to 3 year cycle.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** Data regarding nitrogen and phosphorous in surface and ground waters is available from federal and provincial research organizations, universities, federal and provincial departments, municipalities and the private sector. The sustainability of the quality of the data on nutrient contamination needs to be determined (< one year) in the short term and assessed. Then, through careful selection of target areas across Canada, a nutrient contamination indicator can be developed. Tools such as GIS and geostatistics can be used to analyze and interpret the data.

## APPENDIX 7.7-3: AGRICULTURAL BY-PRODUCTS INDICATOR

**RATIONALE AND POLICY RELEVANCE:** The entry of farm by-products such as silage effluent, livestock manures and milk house liquids into watercourses can result in significant change to aquatic environments. In some cases the presence of these substances in surface or ground water being used for drinking water will result in human and livestock health problems.

Water pollution of agricultural origin often occurs when wastes with high Biochemical Oxygen Demand (BOD) and pathogenic bacteria enter watercourses. High BOD substances such as silage liquors and livestock manure, can create rapid and severe oxygen depletion of the water. In order to develop an agricultural waste indicator,it will be necessary to establish a comprehensive set of quality objectives. Currently guidelines and standards exist for pathogenic bacteria only.

An agricultural by-products indicator will report contamination in relation to established water quality guidelines thereby demonstrating the sector's performance.

**LINKAGE WITH OTHER ISSUES:** The availability of land and disposal systems for the appropriate management of livestock and other wastes is quite variable. As such this indicator is linked with soil management practices and nutrient balance of the soil and land resource issue.

**REPORTING PARAMETERS AND MEASUREMENT UNITS**: Parameters and measurement units may include, the number of bacteria /100 ml relative to established thresholds; application of waste per year in excess based on the carrying capacity and suitability of soils; and the suitability of the land and the climatic influence. BOD levels in the water will also be considered as a parameter, mg/L.

**SPATIAL SCALES:** Design of assessment protocols to measure the impact of agricultural wastes, given the variance in climate, soil types, waste origins and application situations, should include such criteria as: seasonal uptake of nutrients, cropping patterns, cropping calendars, proximity of watercourses and water supply sources, etc. Meaningful monitoring should focus on nothing smaller than farm/watershed/aquifer scale.

**TEMPORAL SCALE:** In monitoring the relationship between farm management practices and water quality (particularly surface water), a seasonal as well as a annual scale would be most meaningful.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEPS:** Further review of available data along with additional resources to develop of special and meaningful indicators.

## APPENDIX 7.7-4: SOLIDS LOADING INDICATOR

**RATIONALE AND POLICY RELEVANCE:** While sediment loading of surface and ground water is a natural occurrence some agricultural management practices, have resulted in elevated levels of soil, organic matter, and\or chemical contaminants particularly in surface water bodies. Problems frequently associated with increased sediment loads include deterioration of plant and fish habitat, water clarity, taste and increased toxicity due to salts and chemicals. The indicator reports the sector's performance relative to established guidelines and as interpreted, indicates the sector's ability to conserve the soil and water resources.

**LINKAGES WITH OTHER ISSUES:** This indicator is directly linked with the intensity of human activities in the area, physical and chemical characteristics of the soil, and land use patterns. Conversely, numerous soil conserving production practices have been developed which serve to conserve the natural land base and preserve water quality and the aquatic habitat.

**REPORTING PARAMETERS AND MEASUREMENT UNITS**: Sediments loading values may be reported in mg/L for a sample or tonne/km$^2$/yr for a stream yield. An indicator ratio (e.g., percentages of total suspended and dissolved solids) will be an expression of observed loading in comparison to established guidelines.

**POTENTIAL SPATIAL SCALE:** Data should be collected on the basis of specific geographic grids. Sediment loading measurements of larger streams and water bodies in diverse landscapes will present interpretation problems.

**PROPOSED TEMPORAL SCALE:** The temporal scales will vary according to geographic characteristics of a region. For example, in wet zones water samples could be collected on a daily basis or after each major shower activity. In arid or semi-arid regions a seasonal reading reflecting minimum soil cover may be more appropriate.

**FEASIBILITY OF DEVELOPMENT AND NEXT STEP:** Data is available from federal and provincial agencies. In the near-terms efforts should be based on the Environment Canada sediment database. The selection of reporting stations will increase the sensitivity to the impact of agricultural practices.