8. AGRI-ENVIRONMENTAL INDICATORS AND MONITORING

8.1 The Need for Agri-Environmental Indicators

The use of indicators for direct measurement of complex systems is rising in many jurisdictions. This is because it is difficult or impossible to measure the cause and effect of a single human activity (or its change) over large areas of the earth's surface with any scientific certainty through routine monitoring or by specific experiments. Measuring the changes in state of general indicators which are known to be associated with certain environmental relationships is possible, however. For example, it is has been proved through scientific methods that certain fish species cannot live in water polluted by certain chemicals or combinations of chemicals. Instead of trying to measure the presence or absence of specific chemicals, the presence of absence of these species is an indicator of whether the chemicals are present or not.

Indicators are used in social and economic domains as well as the natural or the agricultural environment. For example, The Gross Domestic Product (GDP) of a country is an indicator of economic performance, but has nothing to say about how an individual company's business is doing. Other social indicators are the number of infant deaths per 1000 births, or the percentage of literacy in a country. These indicate the general health and social development of the country but say nothing about how any single baby is thriving or how well a person might understand the writing on his or her lease, for example.

Now, many countries have created and are using the idea of environmental and agri-environmental indicators to gauge the state of health of complex natural and farming systems. This adoption of indicators may replace attempts to quantitatively measure the outcome of a change in agricultural practice through on-farm agri-environmental projects.

Agri-environmental programs implemented on individual farms aim to abate the non-point source pollution associated with farming or promote a large number of other environmentally beneficial outcomes (see section 4: Actual and Potential Agri-Environmental Benefits). Unfortunately, these outcomes are difficult to measure in a way which offers absolute proof of program effectiveness, using the usual methods and tools of science. That is to say, it is very difficult to know with any certainty whether a measurable change in, for instance, soil or water downstream in a watershed can be directly associated with a known change in, for instance, management practice on a single farm upstream.

Still, paired watershed and paired site studies are done by researchers in an attempt to find a direct cause and effect relationship, such as by Steven Murphy, University of Waterloo (personal communication, December, 2001). In such experiments, one watershed is used as a control while the other is subjected to changes in practice. Comparisons of measured environmental parameters are made before and after a change in practice and assumptions made about changes in process within the system.

This type of study can be said to treat the problem as a laboratory experiment. Unfortunately, both the assumptions underlying the scientific methods used, and the results of such studies are problematic at many levels (personal communication, Tracey Ryan, Grand River Conservation Authority, 2001; Dale McKeague, AAFC – CARD, 2001). Among one of these problems is that in attempting to isolate the problem for measurement, scientific method “holds constant” many possible environmental variables, while a single one is investigated. This may be an invalid assumption, which leads to an incomplete accounting for all factors in a complex system. Many investigators now choose to use the holistic approaches of ecology, understanding that this consists of a complex web of constantly-changing relationships, rather than a set of perfectly-known cause-and-effect events.

A separate problem of trying to accurately and consistently measure the environmental changes associated with agri-environmental incentive programs concerns costs. Effective monitoring for establishing proof of this sort is prohibitive, far beyond the routine environmental monitoring which governments or individuals now undertake to establish the general state of the environment.

Another major problem of treating farms within watersheds as laboratory experiments is the complexity of agro-ecosystems themselves and the number of uncontrolled intervening events and unmeasured variables which may occur during the experiment. For example, the concentration in parts per million of *E. coli* in a stream before and after the installation of a nutrient management system may have something to do with the change in practice, but may also have a lot to do with dilution from the amount of rain which falls or some other uncontrolled event. Separating the two is almost impossible. This makes controlled comparison of before and after environmental states very difficult.

Because of these and other difficulties, the concept of environmental indicators (see Glossary) has been developed to help in both the monitoring of the state of the environment and to evaluate its change over time through changes in land use or management practices, types of production, or other agents of change. Variations over time in carefully selected environmental indicators can be associated with positive or negative environmental outcomes of deliberate change in environmental stewardship. These changes can be used as valid proxies for measuring the environmental outcome of agri-environmental programs. These typically involve policy outcomes regarding:

- wildlife and habitat indicators
- land cover and landscape indicators
- process indicators

(Moxey and Lowe, 1998)

Agri-environmental indicators, then, offer a means of evaluating the effectiveness and outcome of agri-environmental incentive programs at the watershed, ecosystem or even wider scale. Their use is growing among policy-making bodies all over the world.

A large number of governments and international agencies have devoted considerable time toward the establishment of agri-environmental indicators, and each set is related to both the natural environment and its agri-ecosystems and production systems. Quebec's *Union des producteurs agricoles* (UPA, the province's farm union) for example completed a major environmental survey of farm practices in 1999 using environmental indicator concepts (Canada, 2001, AAFC Environment Bureau).

Next is a brief summary of two of several major sets of agri-environmental indicators which have been recently developed. They are relevant to the Ontario context.

8.2 Major Sets of Agri-Environmental Indicators

8.2.1 The Canadian Agri-Environmental Indicator Project - AAFC

Agriculture and Agri-Food Canada (AAFC) has recently completed a report on agri-environmental indicators titled *Environmental Sustainability of Canadian Agriculture: Report of the Agri-Environmental Indicator Project* (McRae *et al., 2001).* It identifies the economic, social and physical driving forces (see Glossary) affecting the environmental sustainability of agriculture and has identified the following agri-environmental indicators for all of Canada:

- soil cover by crops and residue
- management of farm nutrient and pesticide inputs
- risk of water erosion
- risk of wind erosion
- risk of tillage erosion
- risk of soil compaction
- risk of soil salinization
- risk of water contamination by nitrogen
- risk of water contamination by phosphorus
- agricultural greenhouse gas budget
- availability of wildlife habitat on farmland
- residual nitrogen
- energy use

agriculture was done to reveal change between 1981 and 1996 (McRae *et al.*, 2001, p. 189).

8.2.2 OECD Agri-Environmental Indicators

The Organisation for Economic Co-operation and Development (OECD, 2001) has recently produced a thorough and up-to-date treatment of the conceptual basis, science and policy applications of the indicator approach to environmental analysis. This report assembles all pertinent information from 30 of its member states, the European Union (EU) including Canada's set of indicators outlined above.

The report, *Environmental Indicators for Agriculture* is in three volumes and is addressed to policy-makers and the wider public in both the 30 OECD countries and other countries. The report contains a wealth of pertinent information and economic indicators surrounding agriculture production and economy in the countries and regions mentioned above.

Volume 3, *Methods and Results*, groups and treats specific agri-environmental indicators under the general headings given below. It makes suggestions as to policy development in each case and presents methods for measurement and pragmatic action to address the concern covered by each indicator. Brief summaries of their context in Canada are noted, where available:

- **Soil Quality:**

  "Enhancing soil quality is essential for maintaining agricultural productivity. It can be degraded through three processes: i) physical (e.g.

erosion, compaction); ii) chemical (e.g. acidification, salinization); and iii) biological degradation (e.g. declines in organic matter). These degradation processes are linked to changes in farm management practices, climate and technology" … " There are two OECD indicators that address on-farm soil quality: i) risk of water erosion and ii) risk of wind erosion" (OECD, 2001, p. 197).

- Risk of soil erosion by water:
    - reports a decreasing risk in Canada reflecting the combined effects of reduced tillage (linked to conservation and no-till practices, less intensive crop production (including reduced summer fallow, removal of marginal land from production).
- Risk of soil erosion by wind:
    - Reports a 20 –25% decline in risk in the prairies through a combination of reduction in tillage, changes in types of crops and frequency of summer fallow.
- There are other threats to soil quality linked to compaction, water and wind erosion, salinization and acidification and farm chemical pollution. The risk of salinization is declining in Canada and chemical pollution is less than in e.g. Europe, but soil compaction is increasing.

- **Water Quality**

  "The key areas of concern regarding agriculture and water quality are related to nitrate pollution in surface and groundwater; phosphorus levels in surface water; contamination with pesticides; and the harmful effects of soil sediments and mineral salts" (OECD, 2001, p. 227)… " Water quality indicators include both 'risk' and 'state' indicators. Risk indicators estimate the potential contamination of water originating from agricultural activities. When comparing indicators across regions or countries, the point of comparison should not be the level of emissions but rather the risk of exceeding common threshold values. This is because one level of emissions (or a certain type of agricultural practice) may lead to significantly different concentrations in water bodies depending on the location. State indicators measure the actual trends in concentrations of pollutants in water against some threshold value." (p. 231).

  - Water quality risk indicator:
    - Calculated using a formula for broadly uniform soil types.
  - Recent trends:
    - Canada has established two indicators to address the risk of water contamination by nitrogen impacts and phosphorus. They are designed to address several policy needs, including the need to clarify potential impacts, the targeting of remedial policies and programs and the

development of predictive models and systems to assess impacts.

- Water quality state indicator:
    - The nitrate or phosphorus concentration in water in vulnerable agricultural areas.
    - Agriculture is the major source of nutrient pollution of water, although significant point sources also occur (in cities, for example). The extent of groundwater pollution from agricultural nutrients is less well documented than for surface water.
- Agricultural pesticides contamination of water:
    - Direct measurements of pesticides in surface or groundwater are not widely available across OECD countries, mainly because of the high costs of chemical analysis. Often they are not looked for, although they are often found when this is done.
- Soil sediment loadings of water:
    - (there is no mention of Canada in this section. The United States has a National Resources Inventory program which tracks this).
- Salinization of water (Salinisation in the original):
    - Mainly associated with irrigation.
- Other sources of agricultural contaminants in water:

- Agriculture in OECD countries is not a prominent source of water pollution from heavy metals since heavy metal content of fertilisers is limited by regulation and pesticides based on compounds such as arsenic and mercury are prohibited. The increasing use of sewage sludge on agricultural land poses a risk.
- There is an increasing concern related to release of pathogens from animal waste, from remains of hormones and antibiotics from livestock operations. There are also concerns about the parasites cryptosporidia and giardia. (There is no mention here of *E. coli* or other coliform bacteria).
- OECD recommends national cost/benefit accounting systems which take a comprehensive view.

- **Land Conservation**

"The availability of land and water resources is basic to all agricultural activity…An important consideration for policy makers is to take into account the risks that are increased or mitigated by certain land use and management practices in agriculture…Two indicators are being developed by OECD to address land conservation issues, first, the water retaining capacity of agriculture, and second, the off-farm soil sediment flow from agriculture" (p. 255).

- Water retaining capacity:
    - Calculated by a formula depending on the land area, agricultural land use, and water retaining capacity.
    - Information is limited, but trends suggest that water retaining capacity is declining in most OECD countries and therefore an increase in risk of flooding (for example).
    - There is a need to expand the inputs to modelling to refine this indicator.
- Off-farm sediment flow (OFSF):

  Two approaches are used:
    - OFSF risk indicator: the estimated risk of the quantity of soil erosion sediments transferred from farm to off-farm areas and water bodies; by formula.
    - OFSF state indicator: the actual (or state) quantity of soil erosion sediments transferred from farm to off-farm areas and water bodies; by direct measurement.
    - (There is insufficient information to analyse the implications of OFSF or indeed its source).

- **Biodiversity**

  Understanding the relationship between biodiversity and agriculture is still in early stages.

  "The expansion of farm production and intensification of input use are considered a major cause of the loss of biodiversity, while at the same time certain agro-ecosystems can serve to maintain biodiversity…The main focus of policy actions in the area of biodiversity has been to protect and conserve endangered species and habitats, but some countries have also begun to develop more holistic national biodiversity strategy plans (which incorporate agriculture)" (p. 291).

Indicators being developed concern genetic diversity, species diversity, impact of agriculture on wild species and impact of non-native species. Genetic diversity provides the means to improve crop and livestock yields.

There has been a tendency to move from a reliance on "landraces" bred and adapted over many generations to "hybrids" and most recently through genetic manipulation through new biotechnologies. There is a concern about declining diversity of gene material as single varieties become widespread. Breeding commercial species with wild relatives plays a crucial role.

"Richness" of biodiversity in farming differs according to area and cropping types and systems. Farming systems based on multiple crops and livestock with natural pasture areas are richer in biodiversity than monocultural farms.

- Genetic diversity indicators:
    - Total number of crop varieties/livestock breeds that have been registered and certified for marketing.

        - The share of key crop varieties in total marketed production for individual crops.
        - The share of the key livestock breeds in respective categories of livestock numbers.
        - The number of national crop varieties/livestock breeds that are endangered
    - Species diversity:
        - Trends in population distributions and numbers of wild species related to agriculture.

          There is no comprehensive national system in place in Canada to monitor the diversity of wild species on agricultural land.
        - Non-native species. Tracking the range, abundance and distribution of non-native species which are also pests of agriculture.

- **Wildlife Habitats**

  "All land, including agricultural land, provides habitat for wildlife (flora and fauna), but its composition and quality [is] highly variable. Agricultural activities can impact on wildlife and their habitats directly by the conversion of uncultivated natural habitats to crops or forage, and indirectly through disturbances of these habitats, such as the effects of elevated pollutant discharges.

OECD countries are paying greater attention to improving the quality of habitat on farmland because of the growing value society is placing on such habitats as sites of environmental and recreational value" (p. 331). Six indicators are being developed for Wildlife Habitats; five to monitor the state and trends in intensively farmed, semi-natural, and uncultivated natural habitats. The sixth is a habitat matrix, which identifies and relates the ways in which wild species use different agricultural habitat types.

- Intensively farmed agricultural habitats:
  - 1) the share of each crop in the total agricultural area;
  - 2) the share of organic agriculture in the total agricultural area. Organic agriculture is associated with a greater amount of other species.
- Semi-natural habitats; measured by the share of the agricultural area covered by semi-natural agricultural habitats:
- Uncultivated natural habitats:
  - 1) net area of aquatic ecosystems converted to agricultural use;
  - 2) area of "natural" forest converted to agricultural use.

    More is known about conversion of agricultural areas to aquatic habitats than the reverse.
- Habitat matrix:

  This identifies and relates the ways in which wild species use different agricultural habitat types.

    - The methodology recognises that all farm land has some value as habitat, including uncultivated natural land and man-made features (e.g. farm buildings).

- **Landscape**

  "Agriculture plays a key role in shaping the quality of landscape, as in many OECD countries farming is the major user of land. Agricultural landscapes are the visible outcomes from the interaction between agriculture, natural resources and the environment, and encompass amenity, cultural, and other societal values. Landscapes can be considered as composed of three key elements: landscape structures or appearance, including environmental features (e.g. habitats), land use types (e.g. crops), and man-made objects or cultural features (e.g. hedges); landscape functions, such as a place to live, work, visit, and provide various environmental services; landscape values, concerning the costs to farmers of maintaining landscapes and the value society places on agricultural landscape, such as recreational and cultural values…The challenge for policy makers, because landscapes are often not valued through markets, is to judge the appropriate provision of landscape and which landscape features society values, and assess to what extent policy changes affect agricultural landscape" (p. 365).

  Many public and private schemes exist in OECD countries for conservation of agricultural landscapes, many covering multiple objectives. Little is known about costs incurred by farmers in landscape improvement. Non-market valuation studies reveal that agricultural landscapes are highly valued in many cases, although this varies considerably. “These studies also reveal that the landscape surveyed today is the preferred landscape, landscape’s value decreases with greater distance from a particular site, heterogeneity and ‘traditional’ elements are given a higher value over more uniform and newer landscapes, while landscapes perceived as overcrowded have a low value” (p. 365)…

“A large number of OECD countries have legislation which explicitly recognises the importance of the recreational, cultural, heritage, aesthetic and other amenity values embodied in agricultural or other landscapes” (p. 366). They could take the form of economic incentives, regulatory measures, or community and voluntary based systems.

Internationally, landscapes are given attention, as e.g. UNESCO’s World Heritage List of cultural landscapes.

Demand for provision of landscape amenity is increasing but “farmers tend to undersupply landscape, which is a public good arising from agricultural activity, as they are usually unable to charge for its provision and may be unwilling to bear the cost of landscape conservation” (p. 367).

There are two basic types of landscape: natural and man-made, or cultural landscapes resulting from the interaction of human activity and the environment. Various landscape typologies are being created. Canada has a framework which has three levels of spatial detail ranging from small to large: Soil Landscapes of Canada (SLC) polygons, eco-districts, ecoregions to ecozones. The SLC is extensively used for agri-environmental analysis in support of agricultural policy in Canada. There is a need for a holistic approach in developing indicators. The projected purpose will be to:

- Landscape structures:

  Identify the main components that are commonly associated with agricultural landscape structures (appearance).

  - Through environmental features, encompassing mainly landscape habitats and ecosystems.
  - Land use patterns, including changes in agricultural land use patterns and distributions.

  Other ways in which landscape structural indicators could be established would be to define and measure the most important on-going processes by which agriculture affects landscape by e.g.:

  - Expansion-contraction in the total area of agricultural land.
  - Intensification-extensification of agricultural production.
  - Concentration-marginalisation of farm holdings.
  - The introduction of man-made objects could also be used as an indicator.

- Landscape management:
  - The share of agricultural land under public and private schemes committed to landscape maintenance and enhancement.

    This is to monitor the extent to which public/private management schemes have been introduced to maintain and restore these landscapes.
- Landscape costs and benefits:
  - The cost of maintaining or enhancing landscape provision by agriculture.
  - The public valuation of agricultural landscapes.

  This would measure the value society places on landscapes and the costs for farmers of maintaining or enhancing them and is done through public opinion surveys, consumer expenditure patterns (e.g. through recreation or tourism) or non-market valuation, including hedonic price, travel cost and contingent valuation methods to provide a monetary value of societal landscape preferences. These techniques help to estimate the various consumer values attached to landscape and other non-marketed environmental good and services such as “use” value, “option” value and “existence” value (p.381).

8.3 Linking Agri-Environmental Indicators to Ontario Policy and Practice

The aim of Ontario agri-environmental programs is usually plainly stated, often in the brochures which publicize them. The aim of programs generally addresses one or another specific problem systematically identified by farmers, researchers and government. I have suggested ways in which the aim of programs are stated and how their success might be assessed by decision-makers using agri-environmental indicators in section 4: Acutal and Potential Agri-Environmental Benefits**.**

Both the Canadian and the OECD indicator sets have potential relevance to Ontario policy and practice, since both include the wider Canadian outlook. This methodology is clearly the way of the future for monitoring and evaluating future agri-environmental programs in Canada. It will be invaluable for decision-makers to undertake the large task of associating environmental “goods and services” provided by farmers with actual on-farm activities and incentive rates.