ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

ENVIRONMENTAL INDICATORS FOR AGRICULTURE

Volume 1
Concepts and Framework

OECD

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Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

– to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;
– to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
– to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

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FOREWORD

The impacts – both harmful and beneficial – of agriculture and agricultural policies on the environment are a major issue in OECD countries. To identify and quantify the extent of these impacts and to better understand the effects of different policy measures on the environment, the OECD is beginning to develop a set of agri-environmental indicators.

The growing demand for information regarding agri-environmental relationships largely reflects the higher public priority being given to environmental improvement in agriculture. The UN Commission on Sustainable Development, for example, has requested countries to develop indicators to measure progress in reaching sustainable development, including for agriculture, a goal which emerged from the 1992 United Nations Conference on Environment and Development, held in Rio de Janeiro.

Currently, the supply of quantitative information on agri-environmental linkages is inadequate. Without such information, however, governments and other users cannot adequately identify, prioritise and measure the environmental impacts associated with agriculture, which makes it difficult to improve the targeting of agricultural and environmental programmes and to monitor and assess policies.

This study describes how the OECD has started to meet the demand for data on agri-environmental linkages. The work in the OECD is playing a pioneering role by establishing broadly consistent definitions and methods of measurement, and encouraging Member countries to share in their own experience in developing indicators.

Section I of the study sets out the key objectives for developing work on indicators, followed in Section II by a discussion of the overall policy context for establishing indicators. Section III outlines an analytical framework which can assist in identifying and structuring indicators, to contribute to the analysis of agri-environmental linkages and sustainable agriculture. Section IV considers the choice of indicators, within the overall analytical framework, against the criteria of policy relevance, analytical soundness, measurability and the appropriate level of aggregation. Section V describes the main environmental issues in agriculture of relevance to OECD policy-makers, and examines the technical background, appropriate indicators, and aspects of data and measurability related to each issue. Section VI concludes by outlining the future work on OECD agri-environmental indicators, in particular to provide relevant data and calculate indicators.

This publication is the result of work carried out by the Joint Working Party of the Committee for Agriculture and the Environment Policy Committee. The two parent committees approved this report in 1996 and agreed that it be published on the responsibility of the Secretary-General of the OECD.

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ACRONYMS AND ABBREVIATIONS

AEIs	Agri-environmental Indicators
CH_4	Methane
CO_2	Carbon dioxide
CORINAIR	Part of the European CORINE project on air
CORINE	Coordination of Information on the Environment in Europe
DSR	Driving Force-State-Response
EU	European Union
EUROSTAT	Statistical Office of the European Communities
FAO	Food and Agriculture Organisation of the United Nations
GESAMP	Joint Group of Experts in the Scientific Aspects of Marine Pollution (Joint Experts of IMO, FAO, UNESCO, WHO, IAEA, UN, UNEP)
GHG	Greenhouse gases
GIS	Geographic Information Systems
IAEA	International Atomic Energy Agency (UN)
IMO	International Maritime Organisation
IPCC	Intergovernmental Panel on Climate Change
N_2O	Nitrous oxide
OECD	Organisation for Economic Cooperation and Development
OSPARCOM	Oslo and Paris Conventions for the Prevention of Marine Pollution
PSR	Pressure-State-Response
SARD	Sustainable Agriculture and Rural Development
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCC	United Nations Framework Convention on Climate Change
WHO	World Health Organisation

ENVIRONMENTAL INDICATORS FOR AGRICULTURE

I. INTRODUCTION

The OECD is in the process of developing agri-environmental indicators (AEIs), within the overall context of agricultural policy reform and the need to ensure consistency between environmental and agricultural policies. In this regard the indicators will:[1]

- **provide information** to policy makers and the wider public on the current state and changes in the conditions of the environment in agriculture;
- **assist policy makers** to better understand the linkages between the causes and effects of the impact of agriculture and agricultural policy on the environment, and help to guide their responses to changes in environmental conditions;
- **contribute to monitoring and evaluation** of the effectiveness of policies in promoting sustainable agriculture.

The demand for environmental indicators, in the OECD context, originated from an OECD Council meeting at Ministerial level in 1989, which called for a more systematic and effective integration of environmental and economic decision making as a means of contributing to sustainable development. This request was further reinforced at the G-7 Economic Summit in Paris (July 1989) and in Houston (July 1990).

In 1991, the OECD Council approved a Recommendation on Environmental Indicators and Information to "further develop sets of reliable, readable, measurable and policy-relevant environmental indicators".[2] This commitment was reiterated at the meeting of OECD Environment Ministers in February 1996.[3] The indicator work in the OECD is being undertaken in close co-operation with Member countries, and in conjunction with similar efforts in other international institutions, as a follow-up to the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, Brazil, in June 1992.

The discussions on this work amongst OECD Member countries have noted that it is important for OECD to give a lead in establishing a key set of agri-environmental indicators, with as far as possible consistent definitions and methods of measurement that could also be of use to national governments in developing their own indicators. The indicators chosen should cover the range of primary agriculture's impact on the environment which are policy relevant and that are practical to measure, bearing in mind data availability and the resource requirements to collect, process and analyse data.[4]

Following this introduction, **Section II** discusses the policy context of establishing AEIs. **Section III** develops an analytical framework which can assist in identifying and structuring indicators, to contribute to the analysis of agri-environmental linkages and sustainable agriculture. **Section IV** considers the choice of indicators, within the overall analytical framework, against the criteria of policy relevance, analytical soundness, measurability and the appropriate level of aggregation. **Section V** describes the main environmental issues in agriculture of relevance to OECD policy-makers, and examines the technical background, appropriate indicators, and aspects of data and measurability related to each issue. **Section VI,** concludes by outlining the future work on OECD agri-environmental indicators.

II. POLICY CONTEXT

There is a considerable effort underway to develop AEIs among national administrations, international organisations, and non-governmental agencies. The growing significance of work on AEIs across a diverse group of countries and different agencies to a large extent reflects the higher priority being given to environmental improvement in agriculture, due to a greater public interest in enhancing environmental quality.

For many OECD Member countries the growing demand for indicators and other agri-environmental information is partly because governments are being required to provide environmental impact assessments of agricultural and environmental programmes. The demand for more information regarding agri-environmental relationships is growing, not only by agricultural policy makers but also by farmers and other land users, the research community, the media, the general public and international organisations.

International environmental agreements are also leading to the increasing need for governments to monitor their progress under these agreements. The UN Commission on Sustainable Development, for example, has requested countries to use indicators in their annual reports to measure progress in reaching sustainable development, including indicators for sustainable agriculture and rural development (SARD), as defined in Agenda 21, adopted at the UNCED Rio Summit in 1992.[5]

The need for policy makers to address agri-environmental issues has also occurred at a time when many countries are in the process of reforming agricultural policies and implementing commitments under the Uruguay Round Agreement which came into force in 1995. In order to develop coherent agricultural and environmental policies, it is necessary to understand the environmental effects of agricultural policies and agricultural policy reform, including agri-environmental policy measures.

Analysis to assist policy-makers is necessary because the linkages between agricultural activities and environmental impacts are complex, reflecting biological processes, variations in natural environmental conditions, socio-economic factors, agricultural and environmental policies and changes in these policies. These linkages are further complicated due to the spatial variation in the effects of agriculture on the environment within and between different countries, and because the impact of many farming practices on the environment can be gradual and cumulative over time. Work is currently underway in OECD to further understand the impacts of policy measures, and changes in those measures, on the environment in agriculture.[6]

At present, however, there is an inadequate supply of information to meet the growing demand for understanding agri-environmental relationships and sustainable agriculture so as to:

- identify the environmental problems, risks and benefits related to agriculture;
- improve the targeting of programmes that address agri-environmental issues;
- facilitate the monitoring and assessment of policies and programmes.

The OECD has begun work to help meet the demand for more information and analysis of agri-environmental linkages by developing an analytical framework within which these linkages can be examined, and by identifying indicators to assist policy makers, including monitoring progress towards achieving sustainable agriculture, as described in the following section. In establishing AEIs the OECD is fostering the development of broadly consistent indicator definitions and methods of measurement amongst Member countries and encouraging countries to share in their experience of developing indicators for policy analysis of agri-environmental linkages.

III. A FRAMEWORK TO IDENTIFY AND DEVELOP INDICATORS

1. Context of framework

A major challenge is to provide a solid conceptual and methodological basis to support the empirical analysis of agri-environmental linkages, especially in terms of quantifying the impact of agricultural policies and policy changes on the environment in agriculture. In order to better understand agri-environmental linkages, and to identify and develop policy relevant indicators, particular consideration has been given to:

- recognising specific characteristics of the linkages between agriculture and the environment;
- situating agriculture in the broader context of sustainable development, especially in terms of the relationships between the economic, social and environmental dimensions;
- ensuring the framework to structure agri-environmental analysis is largely consistent with that commonly being used in other related work in the OECD and elsewhere.

Certain specific characteristics of agriculture in relation to the environment to some extent distinguish the agricultural sector from the linkages between other sectors in the economy and the environment. Amongst the specific characteristics of agriculture in relation to the environment three are of particular importance.

First, agricultural activities produce a diverse range of harmful and beneficial impacts on environmental quality. Farming can lead to a deterioration in soil, water and air quality and the loss of habitats and biodiversity. But agricultural activity can contribute to environmental benefits such as acting as a sink for greenhouse gases, conserving and also enhancing biodiversity and landscape, and preventing flooding and landslides.

Second, the relationship between agricultural activities and the environment is frequently complex, site specific and non-linear. Agricultural activities can have impacts on the environment which are determined by different agro-ecological systems and physical attributes of the land, the prevailing economic conditions and production technology, and farmers' management practices in relation to natural conditions.

Third, the agricultural sectors in most OECD countries are characterised by policies delivering high levels of support and government intervention (OECD, 1996*a*). Farmers behaviour can be significantly affected by these policies, in that they influence the level of agricultural production, its location, and the farming practices and management systems employed. Also changes in environmental quality can trigger market and societal reactions which may in turn influence agricultural and environmental policy decisions.

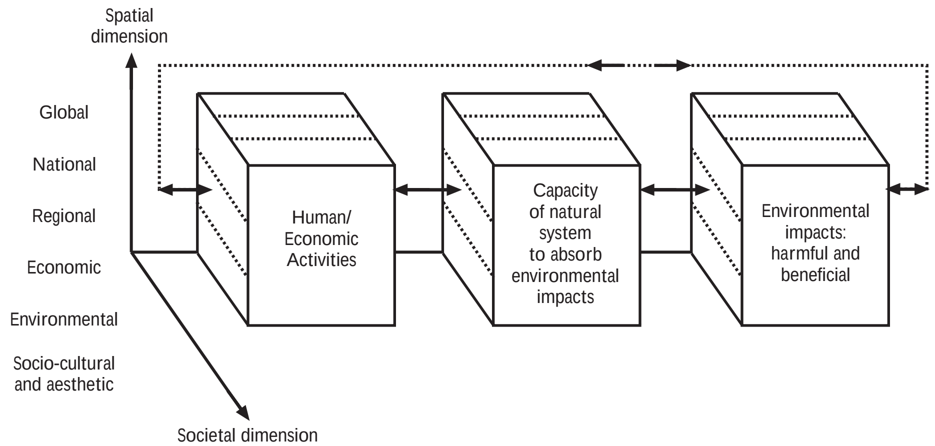
The situation of agriculture needs to be considered in the broader context of sustainable development. Although the concept of "sustainability" is open to diverse interpretation, there is broad agreement that it encompasses economic, social and environmental components (OECD, 1995*c*). In order to foster sustainable development strategies, a clearer comprehension of the linkages between the economy, society and the environment is widely recognised. Figure 1 provides, in a simplified view, the main components, linkages and feedbacks which are of importance in the analysis of sustainability. The figure suggests a sequence of cause and effect as follows:

- *human activities,* such as agriculture and economic developments, and modifications to them in the form of plans, programmes, and policies are linked to the
- *capacity of natural systems,* including agro-ecosystems, to absorb the effects of human activities on the environment, and determine
- *environmental impacts,* both harmful and beneficial, and the long term sustainability of the ecosystem.

Understanding this sequence, and the components and processes involved, may be expected to lead to some feedback through the modification of human activities (Midmore, *et al.* 1995). In an agricultural context this can occur through changes in farmers' behaviour and policy responses, where these are perceived or known to threaten long term sustainability, and to the extent that they are reflected in costs and market signals. The analysis of sustainability encompasses the:

- *spatial dimension,* which ranges from the field, farm, watershed, regional, national through to the global scale;
- *temporal dimension,* in terms of the time period over which sustainability is viewed;

◆ Figure 1. ***A simplified view of the main components and linkages in the analysis of sustainability***



Source: OECD Secretariat, 1996, adapted from Midmore, *et al.* 1995.

- *societal dimension*, covering economics, socio-cultural and aesthetic values and attitudes, as well as the environment.

Particular consideration has been given to ensure consistency with the OECD programme on developing environmental indicators and with other parallel efforts, in Member countries and international organisations and agencies in developing their work on indicators. Many of these efforts use the Pressure-State-Response (PSR) framework or some variation of the framework, in which indicators are then developed, as follows:

- *pressure* on the environment from human and economic activities, lead to changes in the
- *state* or environmental conditions that prevail as a result of that pressure, and may provoke
- *responses* by society to change the pressures and state of the environment.

Using the PSR framework as a basis to develop agri-environmental indicators has been influenced by the general economy-wide environmental analysis and indicator work. This includes ongoing work by OECD to develop a core set of indicators for environmental performance reviews (OECD, 1994*b*). A variant of the PSR framework is also being used by the UN's Commission on Sustainable Development to develop indicators for sustainable development, as noted in the previous section. The UN work accommodates for the social, economic, institutional and environmental dimensions of sustainability through a Driving Force-State-Response framework (UN, 1995).

2. The Driving Force-State-Response framework: definitions and scope

The framework outlined in this report to analyse agri-environmental linkages and develop AEIs is a modified form of the PSR, the **Driving Force-State-Response (DSR) framework.**[7] This framework takes into account the specific characteristics of agriculture and its relation to the environment; the consideration of agriculture in the broader context of sustainable development; and the work already underway in OECD Member countries and other organisations to develop their work on indicators. The approach adopted here is also broadly consistent with the modified PSR framework used by OECD to develop other sectoral environmental indicators, for example in the energy and transport sectors.

The DSR framework addresses a set of questions related to the complex web of agri-environmental linkages and feedbacks, including:

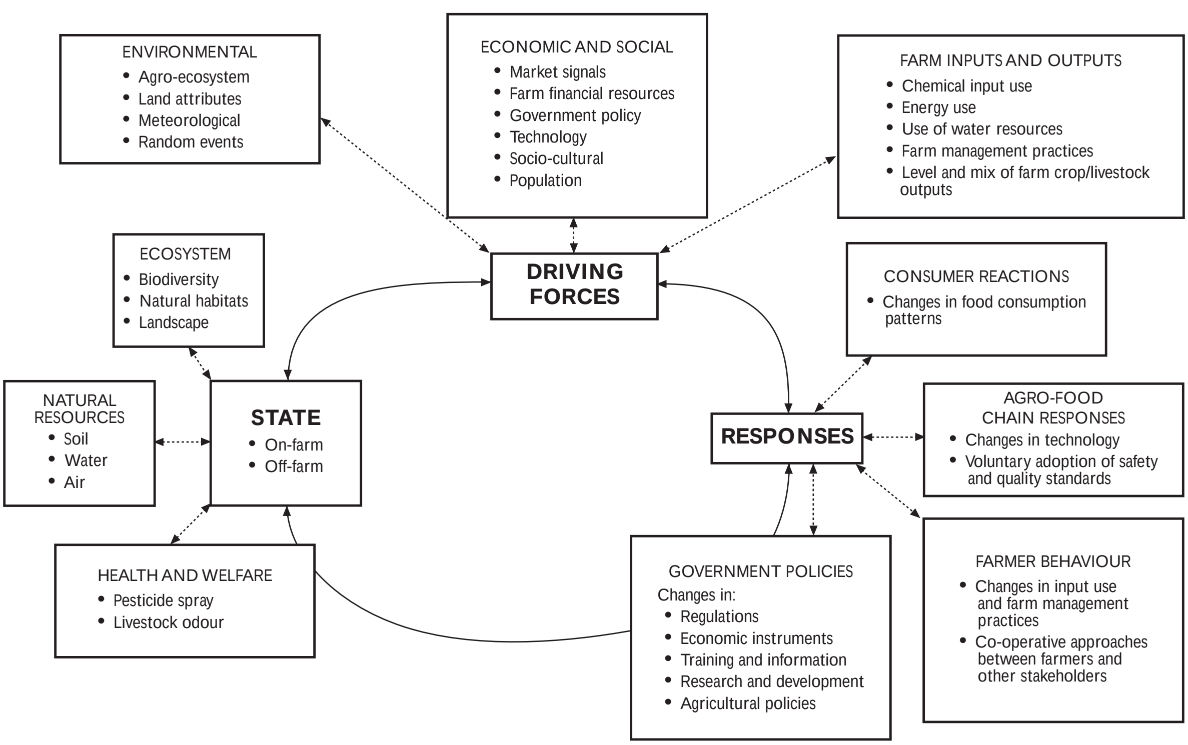
- What is causing environmental conditions in agriculture to change (*driving force*)?
- What effect is this having on the state or condition of the environment in agriculture (*state*)?
- What actions are being taken to respond to changes in the state of the environment in agriculture (*response*)?

In addressing these questions the DSR framework can provide a flexible framework in which analysis can help to:

- *improve understanding of the complexity of linkages and feedbacks between the causes and effects* of agriculture's impact on the environment, and the responses by farmers, policy makers and society to changes in agri-environmental conditions; and,
- *identify indicators* to explain and quantify these linkages and feedbacks.

The DSR framework consists of a vast array of human-environmental interactions, as illustrated in Figure 2, involving different feedbacks and linkages. For example, soil sediment run-off from agricultural land into river systems may impair recreational activities such as fishing, although the rivers (*i.e.* the natural system) may easily be able to absorb the sediment. In the context of analysing agri-environmental issues and developing policy relevant indicators, the DSR framework is essentially a sub-set of the framework outlined for the analysis of sustainable development shown in Figure 1. The following paragraphs outline in more detail the components and logical sequence of linked steps in the DSR framework.

◆ Figure 2. ***The Driving Force-State-Response framework to address agri-environmental linkages and sustainable agriculture***



Source: OECD Secretariat, 1996.

Driving forces are those elements which cause changes in the state of the environment. These include:

- *natural environmental processes and factors,* including the agro-ecological system, the physical attributes of the land, meteorological conditions, and random events such as earthquakes;
- *biophysical inputs and outputs at the farm level,* covering the use of chemical inputs, energy and water resources; farm management practices; and decisions taken in terms of the level and mix of agricultural commodities produced;
- *economic and societal driving forces,* encompassing reactions to economic and policy signals received from markets and governments; variations in the level and composition of farm financial resources; changes in technology; cultural attitudes and public pressure; social structures; and population growth.

The concept of "driving forces" recognises that agricultural activities can both produce *beneficial impacts* to enhance environmental quality, for example by increasing the water storage capacity of certain agricultural systems which may ameliorate problems of soil erosion, landslides and flooding, and also have *harmful impacts* on the environment, such as the excessive use of fertilisers and pesticides and inappropriate management practices. Driving forces also accommodate a broader coverage of the influences affecting the environment in agriculture and sustainable agriculture, including farmer behaviour, government policies, economic, social, and cultural factors.

The state or condition of the environment in agriculture, refers to changes in environmental conditions that may arise from various driving forces. The impact of agriculture on the environment can occur both on-farm and off-farm, for example the effects on biodiversity and climate change, and operate at various temporal and spatial scales from the field through to the global scale. While the state of the environment in agriculture encompasses a wide range of different elements, it can be broadly categorised into the following sub-categories of the:

- *state of the natural resources,* used in agricultural production – soil, water and air – covering their physical, chemical and biological condition;
- *composition, structure and functioning of the ecosystem,* affected by agricultural activities, including biodiversity and natural habitats, while for some countries the inclusion of the man-made environment, such as agricultural landscapes, is also an integral part of this sub-category;
- *state of human health and environmentally related welfare,* including for example the risk to human health from pesticide spraying and the public nuisance caused by odours from intensive livestock production. The range of issues in this sub-category may vary greatly from country to country depending on where the boundaries of agri-environmental issues are drawn, and the importance society attaches to these issues.

An important consideration when examining the "state" component in the DSR framework is to identify the share of agriculture in the environmental media or issue concerned, and to assess its importance for policy purposes. Typically, agriculture is only one amongst other activities in the economy which has an impact on the state of the environment. For example, river and groundwater water quality may be the combined result of agricultural and industrial activities and the disposal of urban waste. A further aspect in this context is that while agriculture can affect the state of the environment, changes in environmental conditions can also impact on agricultural production activities, such as through acid air emissions or ozone depletion.

Responses refer to the reaction by groups in society and policy makers to the actual and perceived changes in the state of the environment in agriculture, the sustainability of agriculture and to market signals. The responses include:

- *farmer behaviour,* by changes in input use, farm management practices, such as integrated pest management, and cooperative approaches between farmers and farmers and other stakeholders;
- *consumer reactions,* through altering food consumption patterns, including preferences for "organically" produced foods;
- *responses by the agro-food chain,* with changes in technology to produce less toxic pesticides and the voluntary adoption of better safety and quality standards by the food industry;

- *government actions*, through changes in policy measures, including regulatory approaches, the use of economic instruments such as subsidies and taxes, training and information programmes, research and development, and agricultural policies.

3. Linkages between driving-force, state and response

Analysis of the linkages between driving forces, state and response is a key element in shedding light on the relationship between the causes and effects of agriculture's impact on the environment to better guide policy makers in their responses to changes in environmental conditions in agriculture. At this stage of the OECD work and in analysis elsewhere, however, these linkages are not yet fully developed.[8] Significant further work needs to be undertaken on the linkages between indicators in the DSR framework, before causal relationships and feedbacks can be better understood and easily expressed for use by policy-makers and other stakeholders.

Analysing agri-environmental linkages in the DSR framework highlights the need to develop knowledge not only of the physical, chemical and biological factors that relate variations in agricultural practices, input use and production to changes in environmental quality, but also to improve knowledge of the economic, socio-cultural and policy factors that determine and influence the effects of agricultural activities on the environment. The examination of the agri-environmental issues and related indicators, outlined in Section V, below will contribute to further analysis in understanding the linkages between agriculture and the environment.

The driving forces are not always sufficient to explain changes in the state of the environment, because the environment in agriculture has the capacity to absorb some stress. Moreover, a particular change in the state of the environment may not easily be quantified and interpreted as either beneficial or harmful in all cases, especially where judgements on environmental quality are affected by evolving societal and cultural attitudes. This emphasises the importance of understanding the linkages between policies, agricultural production and environmental quality, to help guide responses by policy makers to changes in environmental conditions in agriculture.

The DSR framework outlined here is essentially a working tool with the possibility of its components being modified as understanding of agri-environmental linkages improves and as agricultural and environmental policy goals evolve. This process is being complemented by other policy related analysis undertaken by OECD, which could help towards the development of a policy relevant set of AEIs.[9]

Structuring work on indicators in the context of the DSR framework should ensure that indicators are not developed in isolation but can provide insights for policy makers as to the economic, social and environmental linkages and components of sustainable agriculture. In this respect it is worth noting that the interpretation of any one indicator may need to be complemented with other indicators, and be seen within the overall context of the set or appropriate sub-set of indicators.

It will be important, as OECD work progresses, to consider how the linkages of all the elements in the DSR framework might be quantified to better understand, monitor and evaluate agri-environmental linkages and sustainable agriculture. The initial focus of the work is on identifying and developing appropriate indicators for each of the thirteen agri-environmental policy issues outlined in the following section. Moreover, work is also underway to better understand the broader linkages between the key components in the DSR framework – economic, social, and environmental – to assist in further policy analysis, and in monitoring progress towards achieving sustainable agriculture.

IV. SELECTION CRITERIA FOR AGRI-ENVIRONMENTAL INDICATORS

There are potentially a large number of indicators that could be developed to help quantify the various components and linkages in the DSR framework. To assist in the choice of an operational set of indicators within this framework each indicator is examined against four general criteria:

- policy relevance;
- analytical soundness;

- measurability;
- level of aggregation.

1. Policy relevance

The criterion of policy relevance relates to those agri-environmental issues identified in the DSR framework as being of importance to policy makers. While the list of issues is evolving and must be flexible so as to incorporate new issues or abandon old ones, those shown in Figure 3 are currently of major relevance to policy makers in OECD countries. There is a need to recognise, however, that the relative importance of each issue will vary among countries, reflecting their particular environmental and agricultural policy concerns.

Figure 3. **Selected key agri-environmental issues of relevance to OECD policy makers**

1. SOIL	Soil salinisation, acidification, trace element balance, toxic contamination, compaction, waterlogging, and levels of soil organic matter, soil productivity, soil erosion and landslides.
2. WATER	Surface, ground, and marine water quality affected by the run-off or leaching of nitrogen, phosphorous, toxic pesticide residues, acid substances and soil sediment. The use of surface and groundwater resources, the spatial and temporal distribution of water resources, and loading and discharge of surface water.
3. AIR	
Contamination	Air contamination from pesticides, soil, livestock odours, and biomass burning.
Climate change	Emissions of greenhouse gases from agriculture, agriculture as a sink for greenhouse gases, energy use.
Ozone depletion	Stratospheric ozone depletion from the use of some ozone depleting chemicals in agriculture, such as methyl bromide.
4. NATURE	
Biodiversity	Biodiversity of ''domesticated'' plants and livestock; and ''wildlife'' biodiversity.
Habitats	Wildlife habitats on agricultural land, semi-natural and natural habitats.
Landscape	Landscape features arising from the interaction of topographical features, climate, distribution of biotopes, farming systems, and socio-cultural values.
5. FARM FINANCIAL	Issues, including the financial resources available to farmers, which can influence farmer behaviour in relation to the environment.
6. SOCIO-CULTURAL	Issues, including population balance between rural and urban areas, which can influence the relationship between agriculture and the environment.

Source: OECD Secretariat, 1996.

The indicator should be able to quantify the components and issues described in the DSR framework, and agriculture should be a significant component in relation to the issue. The indicator should also be relevant to an environmental issue in agriculture which policies can potentially address, that is to say within the control of policy-makers. It should also contribute to the understanding and interpretation of these issues, as well as to the analysis of the agri-environmental and sustainable agriculture linkages described in the DSR framework.

2. Analytical soundness

The criterion of analytical soundness concerns, in particular, the extent to which the indicator can establish links between agriculture activities and environmental conditions, and thus refers more specifically to the attributes which provide the basis to measure the indicator. It should also be possible for the indicator to explain a link between agriculture and an environmental issue which is easy to interpret and applicable to a wide set of farming systems. The indicator should also be able to show trends and ranges of values over time, which might be complemented by nationally defined targets and thresholds where these exist. Through a pilot survey of AEIs in OECD Member countries, conducted in 1995, and drawing on the expertise of individual OECD Member countries in specific areas, considerable progress has already been made in highlighting the analytical strengths and weaknesses of the indicators currently being developed, as discussed in the following section.[10]

In some countries *target and threshold values* have been established by policy makers to reflect the choices and standards that they wish to achieve (Adriaanse, 1993). However, comparing and assessing threshold and target values with actual values of an indicator will, in most cases, require further analysis. Deriving target and threshold values may be difficult because not sufficient scientific evidence may exist for determining some environmental impacts. Also certain target and threshold values may not be standardised within a country because of regional variation in natural endowments and environmental conditions. It should be noted, however, that it is the general direction of change and the range of values of the indicator over time within each country which can provide useful information to policy makers.

3. Measurability

The criterion of measurability, relates to the appropriate data available to measure the indicator. The indicator should be developed from established national or sub-national data, preferably using a long time series where this is available given the lengthy time period for many environmental effects to become apparent. Recent OECD work has revealed that while a considerable database exists in OECD countries from which to calculate indicators, problems of data definitions, quality, the regularity of data collection and methods of indicator measurement remain obstacles to progressing the work on certain indicators, as discussed in the next section.

In an effort to overcome some of these difficulties OECD has begun a discussion of developing consistent indicator definitions and methods of measurement between countries. In this process it is important, however, to recognise that the attributes measured for each indicator can be sensitive to specific national and sub-national situations. For example, the relative importance of the indicators to address the agricultural soil quality issue – water and wind erosion, salinisation, acidification, waterlogging, trace element balance and toxic contamination – will vary between and within countries.

In some countries efforts are underway to establish a *ranking* of the extent to which agriculture contributes to various environmental impacts compared to other activities in the economy, and the relative importance of different environmental impacts within the agricultural sector.[11] That work is also part of a process to use indicators for the purpose of adjusting national economic accounts to include environmental externalities. However, efforts to establish a ranking of environmental impacts will be limited until a fuller set of indicators has been estimated across different sectors in the economy.

4. Level of aggregation

The criterion of the level of aggregation seeks to determine at which level (*i.e.* farm, sectoral, regional, national), the indicator can be meaningfully applied for policy purposes and not to conceal more than it reveals. This criterion highlights the issue of encapsulating the spatial and temporal diversity of the environment and the geographical scale of different environmental issues ranging from the farm through to the global scale. Moreover, the extent to which different agro-ecological zones have varying physical resource characteristics and property rights associated with those resources can change the impact of environmental outcomes that may arise from farming in those zones.[12]

In many countries national agricultural data are often collected on the basis of political and/or administrative units, such as sub-national regions, rather than in terms of agro-ecological zones, which may be a more appropriate sub-division of national data for developing AEIs. One emerging possibility to overcome such data problems could be the use of *geographic information systems* (GIS).

Geographic information systems are computer-based and designed to collect, manage, analyse and display spatially referenced data (Taupier and Wills, 1994). The system has the potential to improve empirical analysis of spatially related environmental problems ranging from the farm to the national level. GIS also provides the potential to aggregate information according to agro-ecological zones, often using data already collected at the administrative unit level and may also help overcome the issue of confidentiality with highly disaggregated data.

There is no unique way to address the aggregation issue for each indicator and it is most effectively tackled pragmatically, on a country-by-country, issue-by-issue and indicator-by-indicator basis. Nevertheless, methods to provide national level indicators that take into account spatial diversity are being assessed and developed by OECD and Member countries, both to assist national level policy makers and for the purposes of facilitating international comparisons. For certain indicators some countries are considering, for example, measuring the percentage of farmed area that is below a target or threshold level or calculating a standard deviation around the national mean.

While most agricultural policies are determined at the national level, the environmental effects of those policies will vary because of the spatial diversity of agro-ecosystems within countries. Thus, more work is required to develop methods of expressing national level indicators that can reflect regional diversity within countries where this is appropriate.

The discussion on the level of aggregation of data is also directly related to the extent to which indicator information can be compared internationally. For most indicators differing climatic and environmental conditions mean contrasting agri-environmental information across countries requires careful interpretation, especially in comparing the absolute levels for each indicator. One appropriate comparison, however, could be to compare the trends or changes in indicators over time.

V. INDICATORS TO ADDRESS AGRI-ENVIRONMENTAL ISSUES OF RELEVANCE TO POLICY MAKERS

The agri-environmental issues examined in this section have been identified by OECD Member countries as priority areas that indicators should address. The selection of issues and related indicators has evolved from extensive discussions among OECD Member countries, including input from a number of OECD expert meetings, in the context of the DSR framework and general indicator selection criteria discussed in the previous sections.

Those agri-environmental issues so far identified by OECD countries are part of an evolving process, reflecting changing policy priorities and agri-environmental concerns, developments in conceptual analysis, including the DSR framework, and advances in methods of measurement. Thirteen priority agri-environmental issues have been identified by OECD Member countries, for which relevant indicators are being developed, covering:

- nutrient use;
- pesticide use;
- water use;
- land use and conservation;
- soil quality;
- water quality;
- greenhouse gases;
- biodiversity;
- wildlife habitats;
- landscape;
- farm management;
- farm financial resources;
- socio-cultural issues.

The importance of these different agri-environmental issues may vary between countries depending on their *environmental endowments* (for example soil quality), *natural assets and liabilities* (cold countries usually require less pesticide than warm countries), *relative pressure on land resources* (high density population countries would be more likely to emphasise the effects of more intensive agricultural systems and the value of "green spaces"), *income levels* (high income countries may prefer to use more land for nature reserves and be more sensitive to environmental harm than low income countries), and *policy priorities* (these vary according to differing cultural and social attitudes and political goals between countries).

Other policy relevant issues identified in the DSR framework have also been identified by some OECD Member countries for which indicators might be developed in the future. These include, for example, those that address the issues of agricultural energy use, in particular the measurement of energy efficiency in agriculture. In addition, future work may also examine issues and develop related indicators concerning food safety; the relationship between upstream (farm input industries) and downstream (processing and distribution) activities related to agriculture and associated environmental impacts; consumers preference for organic foods expressed through retail outlets and in turn pressure for organic farming practices on farms; and external environmental influences on agriculture, such as acid rain and climate change.

The remainder of this section examines each agri-environmental issue, covering the following elements:

- **A technical description of the agri-environmental issue,** which provides a brief discussion of the technical background to the respective issue, including the relationship between the environmental issue concerned and agriculture, and linkages with other agri-environmental issues, for which indicators are being developed.
- **A description of the indicators or potential indicators,** that can quantify the respective agri-environmental issue.
- **The current data available to develop the indicator,** both in the OECD databases and at a country level, and the measurability difficulties related to the further development of the indicators, including the frequency with which the indicators should be measured given the variable time periods associated with changes in environmental media due to agricultural activities.
- **Further work may be required,** including additional refinements to the methodology to develop indicators, and more conceptual analysis of the links between agriculture and the environment and the definition and identification of appropriate indicators to address the respective agri-environmental issue.

Selected sources and literature related to each issue in this section are provided in respective endnotes. While this is not an exhaustive coverage of the relevant literature it does provide a useful digest for those seeking further information.[13]

1. Agricultural nutrient use[14]

Technical background

An adequate supply of nutrients in the soil, particularly nitrogen, phosphorus, and potassium is essential to crop growth. Nutrients can be lost from the soil through crop production, leaching and soil erosion, and nitrate lost by conversion to nitrogen gases or by volatilisation of ammonia. Deficiency of nutrients, however, can lead to the mining of nutrients and reduced soil quality. Soil nutrients can be replenished through the application of chemical fertiliser, livestock manure and sewage sludge (partially dried residue from sewage treatment). Other farming practices such as planting cover crops and the use of green manure also helps to mitigate the loss of nutrients and in some cases replace nutrients.

Excessive nutrients in the soil can contribute to problems of eutrophication, pollution of drinking water, soil acidification and climate change. Nitrogen and phosphate nutrients associated with fertiliser, manure and sewage sludge use and excess levels of these nutrients in soils, are of greatest environmental concern.

Indicators

To capture how well nutrients are used in the agro-ecosystem the OECD is developing a nutrient balance approach. A nutrient balance, can provide an indicator of the extent to which agricultural production leads to a net surplus (or deficit) of nutrients into (or from) the soil, water or air. However, a deficit or surplus of the nutrient balance, at least over the short term, does not unambiguously indicate a beneficial or harmful environmental impact. This approach draws on the notion of nutrient cycles which are complex and not fully understood.

Several methods exist for measuring nutrient balances, all of which have various limitations, partly depending on the intended level of use of the balance, ranging from the farm to the national level, and also data availability. Two main approaches are being considered to measure nutrient balances, limited at this stage of the work to nitrogen and phosphorous balances, including the:

- ***Soil surface balance,*** which measures the difference between the input or application of nutrients entering the soil and the output or withdrawal of nutrients from the soil. Using nitrogen as an example, the *inputs* include chiefly the application of chemical fertilisers and livestock manure, but the use of other inputs can also be taken into account including, sewage sludge, the atmospheric deposition of nutrients in the soil (which mainly includes ammonia), the nitrogen content of crop residues remaining in fields (*e.g.* roots of potatoes), and the biological fixation of nitrogen by leguminous crops. The *output* consists of the withdrawal of nitrogen from harvested and fodder crops.
- ***Farm gate balance,*** which measures the difference between the nutrient content of farm inputs and the nutrient content of the outputs from the farm. Again using nitrogen as an example, the *inputs* consist of purchased materials such as chemical fertilisers, manure, fodder and livestock, but natural phenomenon, such as the atmospheric deposition of nitrogen in the soil and biological fixation by leguminous crops, can also be included. *Outputs* include the nitrogen content of milk, meat, manure, fodder and cereals, sold of-farm.

Data issues and measurability

A few countries have estimated nutrient balances, using both the farm gate and soil surface methods, while others are beginning work in this area. Much of the basic data required to derive nutrient balances, such as on farm fertiliser use, livestock manure, numbers and composition of livestock, and crop production, are widely available and regularly updated for many countries. The availability of coefficients to determine the quantity of livestock manure produced by livestock and its nutrient content, and the uptake of nitrogen by crops and pasture, however, is more limited including at a regional level, although standardised coefficients have been developed by some countries.

Further work

As environmental problems linked to nutrient imbalances depend on specific agro-ecological features, the information derived from a nutrient balance needs to be combined with knowledge about the production system (*e.g.* the type and density of livestock, crop production economics, and the state of the soil and water quality). Thus, if this indicator is used with other indicators, especially those covering farm nutrient management, soil and water quality, the understanding of the linkage between agriculture and the environment is enriched. In this respect, it should be stressed that a fertiliser per hectare measure provides little information of such linkages.

Further work is already underway in certain OECD countries to refine nutrient balances to take into account, in particular, nitrogen fixation by legume crops; atmospheric deposition and losses of nutrients; and the application of nutrients from using sewage sludge. The development of nutrient balances will also draw on existing guidelines developed by the Working Group on Nutrients of the Oslo and Paris Conventions for the Prevention of Marine Pollution (see OSPARCOM, 1994), as well as extensive work already in progress in a number of OECD Member countries.

Another possible improvement is to relate nutrient inputs to protein outputs (expressed as the sale of livestock and crop products off-farm). The aim would be to provide an efficiency measure of nutrient use in agriculture that could be considered alongside a measure of environmental risk, in other words nutrient inputs and nutrient outputs. Such an approach attempts to reflect one of the key principles of sustainable development in that it includes both the economic benefit and the environmental risk arising from the use of nutrients in agriculture. This approach, however, does not take into account the use of nitrogen on-farm, usually the main source of environmental impact. Moreover, while the approach provides a measure of the efficiency of nutrient conversion into protein, it does not directly address the nutrient deficit/surplus issue, which is critical to this indicator and assessment of environmental risks, in particular those related to soil and water quality.

Further work may also be necessary to reflect regional variations in a national nutrient balance, such as calculating separate balances for cropland and pasture, or estimating the percentage of catchment areas affected by nutrient surplus at different levels of severity. In any case, nutrient balances can only show the risk of environmental damage, not actual pollution. To measure the latter, it is necessary to investigate those variables which reflect site-specific conditions, such as soil type, hydro-geological conditions and climate.

2. Agricultural pesticide use[15]

Technical background

Pesticides have contributed greatly to increased agricultural productivity and crop quality, but once in the environment can accumulate in soil and water, and damage flora and fauna as concentrations in food-chains become high enough to harm wildlife. Pesticide residues also impair drinking water quality, contaminate food for human consumption, cause adverse health effects from direct exposure to farm workers, while some pesticides contain bromide compounds which, when volatised, convert into stratospheric ozone-depleting gases.

A difficulty with establishing indicators that address the issue of agricultural pesticide use is that pesticides vary strongly in their degree of toxicity, persistence and mobility, depending on the type and concentration of their active ingredients, and hence vary in the environmental risk they impose. Also an increase in pesticide use could coincide with a reduction of environmental damage, when more but less harmful pesticides are used, and *vice versa*, which emphasises the need to undertake pesticide use risk assessment. Furthermore, the quantity of pesticides that leach into soil and water depend on, for example, soil properties and temperature, drainage, type of crop, weather, and application method, time and frequency. Moreover, where pesticides are used in combination with certain pest management practices, such as integrated pest management, it may have little or no harmful impact on the environment, pesticide users, or food consumers.

Indicators

The approach being considered by OECD to measure the agricultural pesticide use issue involves:

- classifying pesticide use data into different environmental risk categories, in quantity terms.

This approach combines information on pesticide use with that on pesticide chemistry which influences environmental risk, that is mobility, persistence, and toxicity. However, until OECD evolves a suitable pesticide environmental risk classification system, initially work would begin on collecting pesticide use data, expressed in terms of the quantity of active ingredients per crop and/or per hectare, taking into account the proportion of agricultural land on which pesticides are applied, and the distinction between pesticide use on arable crops and pastures.

Data issues and measurability

Data on pesticide use, in tonnes of active ingredients, are available for most countries, although the time series is not fully complete. The comparability of pesticide data between countries is limited, partly due to differences in toxicity, mobility and persistence of pesticides. Another problem is identifying pesticide use for specific crops and also relevant to agriculture, because some countries include pesticide use for forestry, gardens, and golf courses, for example, in their "agricultural" data. Some countries have data series on the area of land to which pesticides are applied but spatially referenced data are limited. The development of a pesticide risk classification system is not complete for most countries and few, if any, have allocated quantities of pesticides used into different risk categories. A difficulty in this respect is that there are an estimated 300 to 700 active pesticide ingredients, each of which pose a different environmental risk.

Further work

Two key aspects of future work on indicators that address the issue of agricultural pesticide use include development of an environmental pesticide risk classification system, and the allocation of pesticide use data in quantity terms according to this system. However, before a complete pesticide risk classification system is developed, it may be possible to establish a system based on those pesticides already detected in the environment, air and food.

In establishing an appropriate risk classification system it will be necessary to consider national systems already developed as well as seeking international consensus to standardise these different systems. Work is already underway among OECD Member countries to develop a pesticide risk classification system through the OECD Pesticide Forum and related work on pesticides in the OECD Group on the State of the Environment. Links are also being established between OECD and other international organisations working on issues related to pesticide risk, such as EUROSTAT, the FAO and the WHO.

To further develop indicators on agricultural pesticide use it will also be important to consider which environmental risks are of concern, such as impacts on water and soil quality, wildlife, human health from spraying and contamination of food products, and also the extent of coverage of the hundreds of active ingredients. Further work is also needed to examine the links with other related indicators, especially those covering water quality and farm pesticide management as a means of reducing risks from pesticide use.

3. Agricultural water use[16]

Technical background

Water shortage can be a major impediment to agricultural production and also damage aquatic habitats and wildlife. Agriculture uses water, aside from rainfall, supplied from both surface and groundwater sources. For agriculture to tend towards the sustainable use of surface and groundwater resources, the quantity used from these sources should decrease per tonne of biomass/livestock output. The need to maintain and restore the "natural" state of water resources is an integral part of water management and sustainable agriculture practices. The intensification of agricultural practices in many countries has increased the abstraction rates of limited surface and groundwater resources.

Equally, inappropriate land management practices, such as felling trees on agricultural land, can result in problems of "excess" water with rising water tables leading to salinisation and waterlogging. With the higher demand for water from industrial and public consumers, in addition to agriculture, the growing competition for water resources within the economy is of great concern to policy makers in many OECD countries.

Indicators

Measurement of agricultural water use is being considered in terms of:

- developing water balances for, both the use of surface and groundwater resources by agriculture, together with exploring possible linkages with indicators related to farm management, especially aspects of irrigation management.

Some of the indicators for measuring a water balance include consideration of various water use efficiency equations, monitoring stream and river flows (surface water) and also groundwater levels.[17] Monitoring of water flows and levels might be in terms of measuring the relationship over time between surface water flows and groundwater levels in relation to rainfall within a catchment area. To monitor "excess" water, possible indicators could include measuring groundwater levels and the incidence of flooding. Other additional indicators being examined include calculation of water costs per tonne of crop/livestock output, and estimating the quantity of water recharged into groundwater reservoirs through certain agricultural practices as defined in the agri-environmental issue covering agricultural land use and conservation.

Data issues and measurability

The major issue to be considered in response to developing agricultural water use indicators is the extent to which the use of water resources can be linked to agriculture. At present very little data are available for OECD countries on the extent of agricultural water use from surface and groundwater sources, and where data are collected this is in some cases at five yearly intervals. However, for many OECD countries data are available on overall water withdrawal rates from surface and groundwater sources, without identifying major users in the economy. In many countries the major agricultural use of water supplies is for irrigation. Consequently data on irrigation abstraction rates, combined with information collected in relation to farm management indicators, particularly irrigation management indicators, may help to reflect linkages between agricultural water usage and problems of water depletion.

Further work

Further work is required to develop the water balance approach in terms of the sustainable use of water by agriculture, and also explore the linkages with indicators related to irrigation management. As regards the latter, it is necessary to identify different irrigation techniques and to classify them according to their water use efficiency in relation to a given unit of agricultural output. Work is also needed to examine the spatial aspects of agricultural water use, analyse the problem of separating the agricultural use of water resources from other uses in the economy, and also consider the related issue of water resource pricing.

4. Agricultural land use and conservation[18]

Technical background

The pattern and trends in agricultural land use can have significant impacts for natural resources, biodiversity, wildlife habitats and landscape. Changes in agricultural land use may include land permanently retired from production and maintained for environmental conservation purposes, and also the shift of agricultural land to urban, industrial and recreational uses. Moreover, while agricultural land use can lead to degradation of the environment, certain agricultural practices can also play a role in conserving natural resources, such as soil quality, for which other indicators are being developed. For example, certain nutrient management practices can help to enhance soil fertility and soil structure; some cultivation practices such as terracing can minimise soil erosion; crop and pasture land may provide wildlife habitats; and certain irrigation practices, for example paddy rice fields and construction of dykes, can contribute to the stabilisation of river flow, help prevent floods and landslides and improve the recharge of groundwater reservoirs.

Indicators

The indicators under consideration to monitor changes in *agricultural land use* include measurement of:

- land retired from production and maintained for conservation purposes;
- total agricultural land area in relation to the total land area;
- agricultural land per capita;
- agricultural land shifted to non-agricultural uses, including abandoned farmland;

- shifts in land use from wetlands to farmland.

Indicators under consideration to address *agricultural land conservation*, cover the role of agriculture in ameliorating soil erosion, landslides and flooding, measured by the volume of:

- water stored by agricultural soils and ridges and banks (flood prevention);
- water penetrating into groundwater reservoirs relative to the outflow of water from agricultural lands into surface flows (sustainable agricultural water use);
- soil eroded from sloping agricultural land in the case of abandonment (prevention of soil erosion and landslides).

Data issues and measurability

Data on changes in national land use patterns, both between agriculture and other land uses and within agriculture, are generally widely available for most OECD countries. In many cases, however, these data are only collected every 10 years, while definitions of land use types, such as "permanent grassland" can vary widely between countries. The data required to measure indicators that address the issue of land conservation are beginning to be collected by some countries. However, given the close links between agricultural land use, land conservation and other issues – for example, water use, soil and water quality, farm management, wildlife habitats, agricultural landscape, and socio-cultural issues – there may be considerable scope to utilise this wider range of indicators and related basic data.

Further work

In further developing the indicators of agricultural land use and conservation it will be necessary to define more precisely the linkage between a particular change in land use and land conservation and environmental quality, and thus the establishment of the relevant indicators. It should be noted that understanding these linkages is also of concern to a number of other agri-environmental issues discussed in this report. However, this issue, and related indicators, can provide policy relevant information on the ability of agriculture to provide environmental benefits not captured by other indicators discussed here. It will also be important to identify more clearly the links between land use and conservation and other agri-environmental issues, as already identified above.

5. Agricultural soil quality[19]

Technical background

Degradation of soil results from erosion, chemical and physical deterioration. *Soil erosion* on-farm reduces land productivity, which partly depends on soil structure, tilth and water-holding capacity; and off-farm erosion, affects air and water quality causing damage to aquatic habitats and human health. Erosion also reduces the capacity for soil to fix carbon dioxide and act as a greenhouse gas sink, and impairs water storage capacity in rivers, lakes and reservoirs increasing flooding and damaging water systems.

Chemical deterioration consists of the loss of soil nutrients and organic matter, and accumulation of heavy metals and other toxic elements (from the use of sewage sludge on agricultural land for example), leading to salinisation, acidification, and toxic contamination, while *physical damage* includes soil compaction and waterlogging. Soil contamination from heavy metals and other toxic elements can also originate from non-agricultural sectors, for example, the mining industry.

To varying degrees chemical and physical deterioration of soil stems from natural processes, inappropriate irrigation and soil management practices, land clearing, excessive use of chemical inputs, and the mis-use of heavy agricultural machinery. These issues are of interest to policy makers because some aspects of soil degradation are serious because they are only slowly reversible (declining organic matter) or irreversible (erosion), although the relative importance of each issue varies between countries. Recycling of urban and industrial wastes is also an issue for policy makers regarding the conservation of soil quality.

Indicators

Measurement of agriculture's impact on soil quality is being considered through the development of a soil risk methodology which combines indicators on the:

- vulnerability of soil to various degradation processes;
- extent of soil degradation;
- soil management practices.

The emphasis with this methodology is on measuring "risk" rather than the "state" of soil quality in view of the difficulty and cost of measuring the latter and also of separating out natural impacts from water and wind erosion from the influence of farm practices on soil quality. At present the risk method is most suited to soil erosion and salinity degradation processes, rather than aspects of soil quality such as waterlogging and toxic contamination.

Estimated risk of soil degradation can be expressed in absolute terms (tonnes per hectare), classes of severity (low to excessive) or as a trend (per cent change), taking into account specific agro-ecosystem. This approach provides an integration of information on the natural susceptibility of soil to change with land management practices. Although the soil risk approach does not reveal the extent of environmental damage, it can suggest the degree of soil fragility in some regions.

While the focus is on biophysical processes of soil degradation risk, the economic consequences of degradation are also relevant. Thus, the economic effects of soil degradation could be measured through, for example, the loss of production foregone, using data for trends in yields, and the cost of the rehabilitation of soil degradation.

Data issues and measurability

The methodology to measure the "risk" of potential soil quality deterioration is still in the development stage, although, at least for soil erosion, the Universal Soil Loss Equation in its various forms has been used by some countries to estimate soil erosion rates, which can then be reported in "risk" classes. Countries of the European Union (EU) are beginning to collect some information relevant to soil risk measurement under the EU CORINE (Coordination of Information on the Environment) project, although this estimates risk of erosion for the total land area rather than the agricultural land area. A few other OECD countries have also begun work to estimate soil degradation risk. National data on different types of soil degradation suggests that presently data on the area of land affected by soil erosion and acidification are more widely available than for other aspects of soil degradation, while for some countries data are also available on the toxic contamination of soil.

Further work

Further analysis is required to examine the potential of integrating indicators that address the issue of soil quality with other indicators, particularly farm management. However, some farm management practices are already incorporated into the soil risk methodology outlined above, including the soil cover factor (a function of crops grown and the tillage practices being used). Moreover, the inclusion of some indicators that address the agricultural land use and conservation issue, such as the contribution of agriculture to the environment through its water holding capacity, might be considered in the soil risk methodology.

6. Agriculture and water quality[20]

Technical background

The impact of agriculture on water quality mainly concerns the presence of excessive levels of nitrogen and phosphorus, heavy metals, active pesticide ingredients, acid substances and soil sediments. Excessive *nitrogen and phosphorus* levels from fertiliser use lead to eutrophication which can diminish fish populations. High levels of *heavy metals* in water, originating from fertilisers, can enter the human food-chain through absorption by fish. *Toxic contamination* of water from pesticide use can result from leaching or enter directly when spraying takes place close to surface water. *Acidification* of water may originate from fertiliser and fossil fuel use, and biomass burning.

Soil sediments, washed by wind and rain from cropland and overgrazed pasture, can lead to water turbidity and decrease the sunlight and dissolved oxygen available to aquatic plants and fish, thus reducing fish and shellfish populations. Sediment run-off also decreases water storage capacity in lakes and reservoirs, clogs streams and drainage channels, increases the frequency and severity of flooding and damages water distribution systems.

Indicators

The method under consideration to establish agriculture's impact on water quality involves the integration of the "state" and "risk" approaches to measure surface water (rivers and lakes) and groundwater quality in agriculture:

- The "state" approach, measures observed data on the concentrations in weight/litre of water of nitrogen, phosphorous, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, toxic pesticide residues, bacteria, viruses, ammonium, salinity and suspended matter resulting from agricultural activities.
- The "risk" approach, measures the ratio of the potential contaminant concentration to the tolerable or allowable concentration, and is based on a partial budgeting method for nutrients and pesticides.

Data issues and measurability

The major difficulty with the "state" approach is identifying agricultural sources of pollution, as these are often diffuse and may have effects with a long time lag. Determining the contribution of diffuse pollution sources, such as nutrient run-off from fields, to a given environmental impact is more difficult than for point sources. Also, water is not always an appropriate sampling medium for many farm contaminants which are stored in sediment or may bioaccumulate. Indeed, national data of different types of water pollutants specific to agriculture are limited, although more general data are widely available.

The "risk" approach uses data related to nutrient balances, pesticide use and soil characteristics, for example, and thus incorporates much information addressed by other agri-environmental indicators. A number of countries are beginning to develop risk-based methods to measure water quality, especially as these can be directly linked to agriculture. Such approaches may provide early warning of potential problems and are not costly to monitor for national administrations.

Further work

More work will be required to improve the basic data and methodologies for both the "state" and "risk" approaches to measure agriculture's impact on water quality. The links between this and other agri-environmental issues is being further explored, especially nutrient and pesticide use, land use and conservation, soil quality, and farm management issues. The need to develop methods of expressing the regional diversity of indicators that concern this issue is also necessary, including the comparison against national water quality standards. Work might also be extended to examining the impact of agriculture on marine water quality drawing on other international efforts in this area, such as those by the Joint Group of Experts in the Scientific Aspects of Marine Pollution (see GESAMP, 1990), and the Oslo and Paris Conventions for the Prevention of Marine Pollution (see OSPARCOM, 1994).

7. Agricultural greenhouse gases[21]

Technical background

The greenhouse gases (GHG) contributing to the greenhouse effect and emitted as a result of agricultural activity mainly include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). These gases have varying global warming potentials which can be expressed in CO_2 equivalents. Agricultural CO_2 emissions occur when soil organic matter is oxidised and affected by cultivation or wind erosion. CH_4 is largely derived from ruminant livestock's enteric fermentation and animal wastes, paddy rice fields, and biomass burning. N_2O emissions originate from fertilisers, animal urine, waste storage sites, biomass burning and fossil fuel use.

Agriculture also acts as a GHG sink, with soil a major sink of CO_2 through the fixation of carbon by crop and pasture land, while soil also has a substantial capacity to break down CH_4 into the less active CO_2, although little is known about the fixation of N_2O by soils. In addition, crop and wood production on agricultural land leads to photosynthetic fixation of CO_2.

Monitoring the role of agriculture as a source and sink for GHG is of considerable policy relevance given the international commitments that many countries have undertaken to track GHG under the UN Framework Convention on Climate Change (UNFCC), which came into force on the 21 March 1994. It will be necessary, however, to identify the specific role of agriculture as both a source and sink of GHG in relation to climate change problems relative to other sectors in the economy.

Indicators

To measure the release and accumulation of agricultural greenhouse gases the OECD is developing a:

- net balance of the release and accumulation of carbon dioxide, methane and nitrous oxide by agriculture expressed in CO_2 equivalents.

The net balance method of measurement can provide a better reflection of agriculture's contribution to climate change than just measuring gross emissions, by taking into account the role of agricultural GHG sinks. The need to ensure consistency with other international methodologies to calculate GHG in this area is important.

Data issues and measurability

All methods for calculating GHG are subject to uncertainty, due to the margins of error that are involved with the assessment of emissions and sinks related to agriculture. Furthermore, while the sources and sinks of agriculture are reasonably well known, their magnitude is more uncertain depending on factors relating to soil, climate and management.

Within the context of the UNFCC a data inventory relevant to this issue is being developed through a joint programme (the Expert Group on the UNFCC) of the Intergovernmental Panel on Climate Change (IPCC), the OECD Forum on Climate Change and the International Energy Agency. This work will soon provide an annual inventory of disaggregated data of countries that have signed the UNFCC, as well as policy measures directed towards GHG reduction. Data on GHG in western European countries are also being collected under the CORINAIR Project (part of the CORINE project on air).

Further work

The net balance GHG measurement will require further refinement in terms of including the use of fossil fuel on farm, and clarification of the distinction between farm-forestry and forestry. It will also be necessary to provide information that can reveal the range of uncertainty in estimates of agriculture as a sink and source for GHG, which some studies show can be substantial. Consideration also needs to be given to examining links with the farm management indicator to measure the options made to reduce GHG emissions and/or develop sinks in agriculture.

8. Agriculture and biodiversity[22]

Technical background

The importance of the biodiversity issue has been recognised with the signature of over 150 countries to the Convention on Biodiversity which arose out of the UNCED Rio Summit in 1992. A widely used definition of biodiversity includes three levels, although these are closely related, as follows:

- diversity within species (*genetic level*);
- change in the number of species and their population size (*species level*);
- changes in natural habitats providing the necessary conditions for populations of species (*ecosystem level*).

At the *genetic level,* agriculture uses biological diversity as a reservoir of genes for improving plant and livestock productivity, although developing genetic diversity has sometimes been neglected by agriculture. For example, a decrease of the genetic base of crop production on a large area may increase the risk of pests and disease and require greater use of pesticides to the possible detriment of biodiversity on and off-farm.

The biodiversity of "domesticated" agricultural plant and livestock species is of particular policy relevance because of the potentially higher environmental risks and costs associated with monocultural farming systems. Such farming systems may lead to an impact on biodiversity at the *species level* through exposure to excessive use of nutrients and pesticides and also in some cases "domesticated" species entering "natural" habitats and affecting the number, population and distribution of species. In turn, this leads to the impact of agriculture at the *ecosystem level* of biodiversity which may also involve changes to wildlife habitats through the modification of agricultural landscapes.

Indicators

The development of suitable indicators to address biodiversity in agriculture is complex because of the different levels at which biodiversity operates in agriculture, and indicators to measure biodiversity in agriculture have not yet been established by OECD. Since it is possible to preserve biodiversity *ex situ* and *in situ* the indicators that could address biodiversity in agriculture will need to reflect both approaches, including the measurement of the:

- biodiversity of "domesticated" species in agriculture;
- impact of agriculture on the biodiversity of "wild" species.

Data issues and measurability

A considerable effort is being made in many OECD countries to address the issue of biodiversity in relation to agriculture, at both the conceptual and empirical level. This work is exploring a number of indicators to measure biodiversity, including for example the extent of diversity of varieties of crops and livestock breeds in agricultural production, and whether production is taking place on a narrow genetic base. Also being considered is the estimation of the state of and trends in the genetic reservoir, including in gene banks, which agriculture uses for the introduction of specific characters (genes) into plants and livestock.

Some countries are also monitoring changes in "key indicator" wildlife species (plants, insects and animals) that reside in or are in close proximity to agro-ecosystems. Such "key species" may either be considered as representative of a particular agro-ecosystem habitat and/or are "endangered" or "threatened" with extinction from the habitat.

Further work

Further work on this indicator will need to define more clearly what is the link between agriculture and biodiversity, in particular drawing a sharper distinction between biodiversity of "domesticated" species and the biodiversity of "wild" species. In addition, work will need to focus especially on the significance of site-specificity, as the appropriate scale for some biodiversity issues is at the regional level.

It will also be necessary to evolve methods that can interpret the environmental impact of agriculture on biodiversity. For example, this includes the question as to whether a farm structure with smaller field plots and a denser and more comprehensive network of border elements such as hedges and boundary strips provides more favourable conditions to enhance biodiversity. Additional work will also need to explore the links between this issue and those covering agriculture in relation to wildlife habitats and landscape so as to contribute to a better understanding of how different elements of habitats and landscapes influence biodiversity in an agricultural context.

9. Agriculture and wildlife habitats[23]

Technical background

Many farm practices have an impact on the quality and availability of natural habitats which can lead to effects on wildlife. For example, many bird species have become dependent on the presence of permanent pasture land, semi-natural grasslands and small habitats in the landscape, such as hedgerows. Agriculture also impacts on wildlife that is not directly present on agricultural land, but which is connected through, for example, the downstream affects of nutrients and pesticide residues in water and through changes in the length of the contact zone between farmed land and "natural" habitats. Agriculture can also affect "natural" habitats through the escape of domesticated species, as previously described in relation to the issue of biodiversity. The quality of wildlife habitats might also be affected by agriculture through increased fragmentation, which can lead to damaging effects on species population size and distributions, and the potential loss in species diversity.

Indicators

The indicators to measure agriculture and wildlife habitat have not yet been established, but the following are under consideration, including measuring:

- changes in the area of selected "large-scale" habitats in agriculture such as woodlands, wetlands and pasture;
- fragmentation of habitats both in the agro-ecosystem and "natural" habitats;
- length of the "contact zone" between agricultural and non-agricultural lands.

None of these indicators provide a direct causal link between agricultural activities and impacts on wildlife habitats, although if used in conjunction with other indicators that address nutrient and pesticide use, land use and conservation, and farm management, they may contribute information to establish these linkages. Moreover, the indicators outlined here provide little information on the relationship between changes in the quality of wildlife habitats and agriculture, although the measurement of changes in "key indicator" wildlife species (as described in the discussion on the agricultural and biodiversity issue) and habitat fragmentation could be of value in this context.

Data issues and measurability

Many OECD countries are in the process of measuring changes in the area of wildlife habitats linked with agriculture, especially changes in the area of semi-natural grassland, permanent pasture, woodland, and wetlands, although there are problems associated with the quality and reliability of this data. However, the measurement of the fragmentation of habitats and the length of contact zone between farms and natural habitats is only in the development stage for certain countries.

For some countries data are collected on the number and area of ''officially'' protected habitats, while other countries collect data on ''small-scale habitat features'' such as fieldhedges, open ditches, and stonewalls. A number of countries also have data series concerning key species, especially birds and bird populations. Work is also underway in a few countries to establish information on wildlife habitats by use of satellite based remote sensing in conjunction with analysing this information by the use of geographic information systems.

Further work

In developing indicators to address the link between agriculture and wildlife habitats work is required to define more precisely the scope of wildlife habitats in agriculture and establish the linkages between natural habitats and agriculture, especially in relation to key indicator species and landscape. National legislation and international agreements may be of help in establishing these definitions and linkages. More work has to be undertaken to understand the direction of agriculture's impact on biodiversity. The difficulty of encapsulating the spatial diversity of wildlife habitats into national wildlife habitat indicators also needs to be addressed.

10. Agricultural landscape[24]

Technical background

Landscape can refer to a way of describing agro-ecosystems and semi-natural habitats.[25] An agricultural landscape can also refer to the visual character of the land including its intrinsic beauty, historical features, embodiment of cultural values, reflecting the past and present impact of land use. The specific value of landscapes depends on the pattern of land use, farm practices, composition of farming systems, and the distribution of habitats and man made features like stone walls or historical buildings. The rate of change of these attributes determines how rapidly landscape alters, ranging from its conservation to its complete transformation.

Densely populated countries often consider it necessary to adopt an integrated approach to productive land use to achieve landscape conservation. This integrated approach can take into account both negative environmental consequences of agriculture and the provision of environmental benefits through the functioning of agro-ecosystems. Other countries consider that landscape is connected to public and political preferences based on socio-cultural attitudes and judgements and is not an environmental aspect of agriculture *per se*.

Indicators

Indicators to measure the complexity and diversity of agricultural landscapes have not yet been established by OECD, but some Member countries are beginning to develop indicators, including the measurement of landscape through:

- *estimating the monetary value of landscape,* using economic non-market valuation techniques, such as the contingent valuation method. There remain many conceptual and practical difficulties with these techniques as they can be resource intensive when applied on a large scale, and involve subjective judgements.
- *developing an inventory of physical landscape features,* such as the linear distance of hedgerows, monitoring trends in land use and appearance of key species. A difficulty with this approach is the choice of features or key species to include in the inventory (which will vary among countries and regions within countries), and the problem of assessing whether a change in the inventory represents a positive or negative environmental impact, related to agricultural activities.

Data issues and measurability

In establishing a definition of landscape some countries have drawn on existing policies relevant to landscape, such as those covering areas of special natural beauty. However, much work needs to be done on clarifying exactly which elements constitute landscape in an agricultural context and which can be quantified in terms of maintenance costs involved, landscape values, or physical measurements.

Difficulties in developing suitable indicators to measure landscape arise because the value placed on a landscape and the physical impact of agriculture on landscape is often subjective. Moreover other sectors, such as forestry, and features like villages, may also contribute to rural landscape. Furthermore, it is not easy to determine whether and how agriculture is improving or harming landscape. Indicators of rural tourism may be appropriate as the role of agricultural landscapes in rural tourism can constitute an important source of revenue and rural employment, and provides an incentive to maintain traditional agricultural systems in long-settled regions of certain OECD countries.

Further work

Further work will be necessary to understand the linkages between landscape, agriculture and the environment, and determine appropriate indicators. Additional work might also examine the links between landscape and those covering agriculture and biodiversity and wildlife habitats, by analysing these links at different levels, including, species and genes at the lower level, habitats and man-made landscape features at the middle level, and landscape at the upper level.

11. Farm management[26]

Technical background

Farm management relates to farmer behaviour and technology uptake through a hierarchy of practices ranging from those specific to farm inputs, environmental media such as soil, and practices such as pest control, to whole farm management. While the agri-environmental issues listed in Figure 3 relate to the effects of agro-ecological conditions and the rate and efficiency of input use, they also arise from the choice of management practices and technologies used by farmers in response to local conditions and the mix and level of farm output.

Considerable scientific evidence has linked certain farm practices to environmental harm, but there has also been much research and adoption of techniques which improve environmental quality. Practices in some countries encourage farmers to adopt practices that improve environmental quality and foster sustainable agriculture through various government economic, regulatory and information programmes, while for other countries this is being stimulated through voluntary or cooperative approaches.[27]

Indicators

A number of indicators to assess the environmental impacts of farm management practices are under consideration, including the measurement of:

- ***nutrient management*** – the share of land which is analysed regularly for soil phosphorus; the share of farms using a nutrient management plan; the area of agricultural land which require less than normally recommended nutrient inputs; the area of agricultural land receiving excessive (*i.e.* above recommended levels) nutrient inputs; the timing of slurry application and months of available slurry storage on farm; and the use of low ammonia emission slurry application machinery;
- ***pest management*** – the share of land on which integrated pest management practices are adopted; the use of pest forecasting systems; the area of cropping land on which pesticides are not applied; and the measurement of the efficiency of pesticide spraying equipment in applying pesticides;
- ***soil management*** – the share of land on which soil conservation practices are adopted including the use of winter cover crops, and appropriate tillage practices;
- ***irrigation management*** – the efficiency of water use on irrigated land in terms of the quantity of water used to produce a unit of agricultural output; and the pricing of water to agriculture;

- ***whole farm management*** – the rate of adoption of farm plans or property management plans – which, when fully developed, may contain information relating to economic, farm production and biophysical or environmental factors – either approved by governments or voluntarily.

Data issues and measurability

An important impediment in developing indicators to measure farm management practices is lack of data, although in a few cases data series do exist. To develop the measurability of the farm management issue it will be necessary to define more clearly policy relevant indicators across a broad number of countries and applicability to particular farming systems or agro-ecosystems. It will also be important to evaluate the confidence level in the particular technology or practice being addressed by the indicator; and measure the degree of adoption by farmers of particular technologies and farm practices including participation rates in relevant government programmes or cooperative schemes.

For some countries organic farming systems are being considered as a long term bench mark for the evaluation of apparently environmentally benign agricultural production systems. Major difficulties with developing indicators to address the farm management issue include identifying appropriate from inappropriate management practices. This is because the combination of the quality of the management decision and its timing can make a significant difference between whether the effects on the environment of the practice are adverse or beneficial. Also there is the problem that while one farm management practice may resolve a particular environmental issue it can exacerbate others. For example, reducing mechanical cultivation increases pesticide use, but reduces soil erosion. Increasing hay in rotation reduces pesticide use and soil erosion and may improve soil organic matter, but requires more land to produce the same level of desired cereal output, thus, negatively impacting on wildlife habitats, biodiversity and perhaps water quality.

Further work

Further analysis of farm management practices will be required in terms of defining measurable indicators that can separate out environmentally appropriate from inappropriate practices. Additional work could also explore the relationship with other agri-environmental issues and related indicators. As some countries have already defined certain practices in national legislation, for example "organic farming", while FAO has developed internationally accepted definitions for certain farm management practices, such as integrated pest management, this information could provide an input to develop indicators that address the farm management issue.

12. Farm financial resources[28]

Technical background

The linkages and feedbacks between the level and variation in farm financial resources and environmental impacts are complex. These relationships may vary considerably both within and among countries. On the one hand they depend on farmers skills and ability to manage the financial resources at their disposal, including their adaptability to respond to changes in their financial situation, and whether a farmer is part-time, full time, tenant, owner and engages wage labour. On the other hand, the relationship between farm financial resources and the environment also depends on those influences outside the control of individual farmers, including the physical agro-ecosystem, policy, and the economic and socio-cultural context in which farms operate.

The sources of financial resources to farmers include market returns, off-farm income, loan and equity capital, and transfers from taxpayers (government budgetary support) and consumers (through market price support). The financial resources available to the farm may impact on: the ability to farm; the type, level and intensity of input use and production; the ability to acquire new technologies; the adoption, or not, of environmentally sound production methods, including farmers attitude towards environmental risks; rates of structural adjustment including farm amalgamation, exit and entry; and the pressures for policy interventions.

While all these factors might be associated with environmental impacts to varying degrees, different sources of farm financial resources may have varying environmental implications. This may occur, for example, by affecting behavioural incentives according to the timeframe over which farmers receive various types of financial resources, and the degree of certainty of the flow of resources. For some countries, where environmental protection in agriculture is funded almost entirely by farmers, the level and changes in farmers financial resources will affect their ability to use resources for environmental purposes. Moreover, it will also affect their incentive to adopt practices that promote sustainable agriculture, to the extent that environmental costs are internalised in the financial performance of farmers.

Indicators

The indicators under consideration to address the issue of farm financial resources and the environment include measurement of:

- net farm and off-farm income;
- policy transfers;
- average rate of return on capital employed;
- average debt/equity ratio, on a per farm basis and adjusted for inflation in real terms.

Data issues and measurability

In terms of developing the definitions and collecting basic data to measure each of the potential indicators listed above, while further analysis is required, some elements might be provided through work completed or underway in other OECD activities. These activities include, for example, the annual monitoring of OECD agricultural support policies exercise (OECD, 1996*a*), the work on economic accounts for agriculture, analysis of farm household incomes and the project to develop a set of agricultural structure indicators. A key difficulty, however, is in deciding which of the potential indicators to measure farm financial resources are "driving force indicators" in the DSR framework outlined above.

Further work

More work has to be completed on defining the direction of environmental impact, associated with changes in the level of farm financial resources. Further investigation is also required of the links between farm financial resources, farm management practices employed, and the effect on the environment, taking into account other factors, such as longer term climatic changes and population growth, which may indirectly influence farmer behaviour and environmental outcomes.

13. Socio-cultural issues in relation to agriculture[29]

Technical background

A number of socio-cultural issues in relation to agriculture and the environment and more broadly, sustainable agriculture, would appear to be of common interest to many OECD countries. These include the loss of productive agricultural land to other uses and through land degradation. Also, considered important are rural-urban population changes, in particular the impact of declining or increasing rural populations on the provision and quality of rural amenities, including landscape and agriculture's role in controlling forest fires. Additionally of interest is the education levels and training of farmers in terms of their awareness of environmentally "friendly" and sustainable farming practices. Finally, for example, there is interest in changes in farm structures, ownership patterns and the age composition of the farm population; and also aspects related to the effects on farmers of chemicals and machinery used on farms.

While some of the issues outlined above are relevant to the environmental impacts and sustainability of agriculture, nevertheless, others may be more closely related to the broader socio-cultural structure of rural communities, although the distinction between these two aspects is not always clear. In many cases, however, the issues described here are closely related to those outlined under other agri-environmental issues in this report, for example land use and conservation.

Indicators

Although the importance of socio-cultural issues in the analysis of agriculture and the environment, including sustainable agriculture, is generally accepted, no precise definition of the policy issues nor relevant indicators have yet been established. In view of the description above of the socio-cultural issues of interest to some OECD countries in the context of agriculture and the environment, the following indicators are under consideration, including the measurement of:

- land use changes, especially the transfer of agricultural land to use for urban development;
- changes in population growth and composition, in particular rural-urban changes;
- education and training of farmers, in relation to the adoption of environmental plans and sustainable farming practices;
- farmer health and safety, related to the use of agricultural pesticides and machinery.

Data issues and measurability

There is clearly potential for developing the links between measuring indicators addressing this issue and other agri-environmental issues examined in the report, such as land use and conservation and farm management. For some of the indicators that might be developed to address the socio-cultural issues in agriculture, preliminary work on data and measurement is already underway in various OECD activities, although the focus of this work is in general related to the areas of rural development and structural adjustment in agriculture rather than sustainable agriculture *per se*.

Other work in the OECD is currently examining the implications for the rural economy of agricultural adjustment and diversification, with the preliminary collection of data for this work covering for example changes in regional farm size, income and employment. In addition, work is also being undertaken by the OECD Group of the Council on Rural Development of relevance to sustainable agriculture, such as the development of rural indicators including a set related to social well-being and equity in rural areas and rural employment.

Further work

The key aspect to further work to address the socio-cultural issue in relation to agriculture and the environment, relates to establishing a clear definition of the relevant policy issues and developing indicators that can quantify these issues. Work underway both on other agri-environmental issues, for example land use and farm management, and in other OECD activities, such as on rural development and structural adjustment in agriculture, could be drawn on to help develop the definition of issues and identification of indicators. However, further conceptual work is also required to examine the linkages between the socio-cultural, economic and environmental components in the DSR framework described in this report, and also consider the spatial aspects of these links in developing appropriate indicators.

VI. FUTURE WORK ON DEVELOPING OECD AGRI-ENVIRONMENTAL INDICATORS

While the OECD's work on AEIs is at an early stage, the present report shows that considerable progress has been made in outlining the framework to develop indicators and the method by which indicators should be measured. The further development of the work will also partly depend on the experience gained in calculating indicators. The main elements in future work – outlined in detail on an issue by issue and indicator by indicator basis in the previous section – relate to *conceptual and analytical, data and measurability issues, and the linkages in the DSR framework.*

1. Conceptual and analytical issues

Further conceptual work is required for certain agri-environmental issues to establish more clearly the link between agriculture and the respective environmental issue and identify appropriate indicators, for example, landscape, farm financial resources and socio-cultural issues. Additional work will also be required to develop more precise indicators to quantify some issues and ascertain the extent of data availability and quality, such as the areas of biodiversity and wildlife habitats. Consideration will also need to be given to the interpretation of the trend or change in direction of each (or a sub-set) indicator as showing an improvement or deterioration in the environment.

2. Data and measurability issues

Further work is required to systematically collect data to measure all indicators, improve data quality and fill gaps in data series. For those agri-environmental issues, (such as those identified in the previous paragraph), where additional work is needed to define more precisely both the issue and indicators required, it will also be necessary to establish the extent of data availability and quality to measure the indicators. In the case of agri-environmental issues where several indicators have been identified, further work will be necessary to determine how to combine these indicators into single indexes of, for example, soil quality and water quality.[30]

More work will also be required on the appropriate level of aggregation of each indicator, especially where indicators could provide a misleading interpretation of the environmental performance of a particular region or country. This should entail examining how spatial diversity might be expressed through regional and national level indicators, although it is recognised that the importance of spatial diversity varies between indicators. An important rationale for further OECD work on indicators will also be to improve consistency in indicator definitions and measurement attributes between countries.

3. Linkages in the Driving Force-State-Response framework

To throw light on the linkages between agricultural policies, farm practices and environmental effects, subsequent analysis will need to attempt to quantify the relationships between driving forces, state and responses. This will combine the work on the development of agri-environmental indicators, indicators developed for agricultural policy analysis and agri-environmental policy case studies.

A key part of the work to develop the conceptual and methodological basis of both the overall linkages in DSR framework, and its various agri-environmental and sustainable agriculture components, is being undertaken through the efforts of "lead" OECD Member countries. Essentially the "lead" country approach involves drawing on the specific interest and/or expertise on certain issues which some countries have already established. Thus, for example, some OECD "lead" countries have built considerable expertise in developing nutrient balances or indicators that address the issue of soil quality, while others are examning the predicative capability of AEIs to assess the economic and environmental implications from domestic agricultural policy reform.[31]

Future work, especially in terms of data collection and processing, will also draw on activities already underway in OECD. For example, various agricultural databases already developed, or in the development stage, in the OECD Agriculture Directorate should provide a source of some basic data for AEIs. In addition, OECD work on AEIs is being coordinated with other related OECD activities, including the work of the OECD Environment Directorate, in particular, its work on developing a set of general environmental indicators, and work covering pesticides and climate change; and also the OECD Territorial Development Service programme on rural development.

The OECD Secretariat is also establishing close links with work on AEIs in other international organisations in an effort to avoid unnecessary duplication of effort, notably with EUROSTAT and FAO. The need for co-operation and co-ordination of work between the OECD Secretariat, national governments, and international organisations, is essential in order to make the best use of limited resources both in the Secretariat, Member countries and in other international organisations.

4. Concluding remarks

The overall framework and approach being developed in the OECD to establish a set of AEIs, is also of potential value to many non-Member countries. Interest in addressing agri-environmental issues, developing methods and indicators to monitor agri-environmental impacts is now of growing importance to most countries and regions of the world. The greater interest attached to monitoring agri-environmental impacts is evident by national commitments to the work of the UN Commission of Sustainable Development to develop indicators to measure progress toward reaching sustainable development as defined at the UNCED 1992 Rio Summit under Agenda 21.

While this report has outlined the framework in which to develop AEIs in the OECD, further work over the short to medium term period will mainly need to concentrate on a number of areas with the overall objective of assisting policy makers, including:

- analysis of the overall DSR framework to better understand agri-environmental relationships and sustainable agriculture;
- methodological reflections on certain specific agri-environmental issues where the identification of indicators and methods of measurement need further development;
- collection of basic data and measurement of indicators for those specific agri-environmental issues where the methodological phase of the work is sufficiently advanced.

Moreover, in the future OECD agri-environmental indicator work will need to be regularly reviewed to reflect the emergence of any changing priorities and new concerns. But the underlying priorities for OECD work on indicators will continue to inform policy makers, and the wider public, on the state of the environment in agriculture; assist policy makers to better understand agri-environmental linkages so as to improve policy design and decision-making; and contribute to monitoring and evaluation of the effectiveness of policies to promote sustainable agriculture within the overall context of agricultural policy reform.

NOTES

1. The more **specific demand for work on agri-environmental indicators (AEIs)** derives from the activities of the OECD, in particular to develop indicators as a contribution to:

- the **Joint Working Party of the Committee for Agriculture and the Environment Policy Committee** (JWP) work on analysing agricultural and environmental policies in OECD countries, including the analysis of sustainable agriculture and the links between agriculture, trade and the environment;
- monitoring and evaluating the current state, trends and emerging issues in the agri-environmental area and related policies for the annual report **Agricultural Policies, Markets and Trade Monitoring and Evaluation in OECD Countries** (see OECD 1996*a*) and the **National Policies and Agricultural Trade Country Study** series of reviews;
- **other work undertaken by the Committee of Agriculture,** such as the analysis of structural adjustment in agriculture and related indicators, and rural development; and
- cooperate in **other OECD work** related to the AEIs project, such as the development of rural indicators by the OECD Group of the Council on Rural Development (see OECD, 1994*a*), the activities of the OECD Pesticide Forum (see Grandy and Richards, 1994), and the work of the OECD Forum on Climate Change.

2. The OECD work to meet the requests to develop environmental indicators is mainly undertaken by the **Environment Policy Committee Group on the State of the Environment** and its environmental indicators programme and associated workshops. The key objectives for this work are to develop indicators for (see OECD, 1996*b*):

- monitoring the state and changes in the environment and related human activities, and tracking progress made, including developing environmental indicators. The indicators are included in the OECD Core Set of environmental indicators, and are used as one tool in the OECD series of **Environmental Performance Reviews** (see OECD 1993*a* and 1995*a*). These reviews cover pollution and natural resource management issues, policy integration (economic and sectoral), and international cooperation. It should be noted that these reviews do not systematically address the agricultural sector as a whole, however, agriculture has been referenced in separate sections of a number of country reviews. The OECD Core set of environmental indicators has been published in 1991 and 1994 (see OECD 1994*b*), and an update is under preparation;
- better integrating environmental concerns into economic policies in general through indicators derived from environmental accounting. This involves the development of natural resource accounts, the adjustment of national economic accounts and the creation of satellite accounts for environmental purposes; and
- better integrating environmental concerns into sectoral policies. This work typically covers sectoral trends of environmental significance, interactions between the environment and the sector, as well as economic and policy considerations. Work has already been completed on energy (see OECD 1993*c*), transport (see OECD 1993*d*) and forestry, while work on agriculture is being undertaken through the activities of the JWP referred to in endnote 1.

3. For the Communique of the 1996 OECD Environment Ministers meeting, see *Meeting of the OECD Environment Policy Committee at Ministerial Level – Communique,* OECD Press Release, 20 February 1996.

4. The term "primary agriculture" is broadly defined here to include the production of crops, including grassland and pasture, and livestock products, and includes woodland on agricultural land but not forestry. The issue of forestry, agriculture and the environment has been examined by OECD, see OECD (1995*b*).

5. As part of the UN Commission for Sustainable Development Agenda 21 programme to develop information systems on sustainable development (see UN, 1995), the FAO has begun establishing guidelines for collecting and using indicators related to sustainable agriculture and rural development (SARD).

6. See two recent policy case studies in this context: OECD (1997*a*) and OECD (1997*b*).

7. The discussion in this section on the DSR model draws on US Environmental Protection Agency (1995*a*), World Bank (1995), and World Resources Institute (1995).

8. For a selection of literature that examines the linkages between environmental impacts, farming practices and agricultural and environmental policies see for example Abler (1996); Abler and Shortle (1992); Antle and Crissman (1994); Batie (1995); FAO (1995); Greiner (1994); Hanley (1991); Hrubovcak, Le Blanc and Miranowski (1990); Just and Antle (1990); Just and Bockstael (1991); and Mabbs-Zeno and Antle (1994).

9. Recent examples of related OECD policy work are provided in endnote 6.

10. A pilot survey on agri-environmental indicators in OECD Member countries was conducted in 1995. Its key objectives where to:

- determine which definitions and methods of measurement countries are using in relation to developing agri-environmental indicators; and
- establish the national availability and quality of data and any coefficients required to measure proposed indicators.

11. The issue of ranking of environmental issues between sectors in the economy and within agriculture is discussed by Adriaanse (1993); Haan, Keuning and Bosch (1993); and in the context of agriculture's contribution to global warming see Born, Bouwman and Leemans (1992).

12. The difficulties associated with the spatial dimension in developing AEIs is further discussed in the Agricultural Council of Australia and New Zealand (1993, pp. 14-19) and Basher, Greer and Korte (1993).

13. It should also be noted that a number of more general references provide a good overall summary of most of the issues and indicators in this report, including: Agricultural Council of Australia and New Zealand (1993) and (1996); Commission of the European Communities (1994); Environment Challenge Group (1995); European Environment Agency (1995); Hodges (1973); INRA (1995); McCann (1995); McRae (1995); McRae and Lombardi (1994); National Research Council (1989); New Zealand Ministry of Agriculture and Fisheries (1995); UK Department of the Environment (1996); UN Economic Commission for Europe (1992), US Department of Agriculture (1994). The US Department of Agriculture, Natural Resources Conservation Service, Natural Resources Inventory Division, Washington DC, also regularly publishes notes on different aspects relevant to agriculture and environmental monitoring, see the NRCS/RCA Issue Brief series, including recent Issues Briefs on *Agriculture and Climate Change* (Brief 3, October 1995); *Wetland – Values and Trends* (Brief 4, November 1995); *Soil Quality* (Brief 5, November 1995); *Animal Manure Management* (Brief 7, December 1995); *Water Quality* (Brief 9, March 1996).

14. The calculation of an agricultural nutrient balance is being examined by the Working Group on Nutrients of the Oslo and Paris Conventions for the Prevention of Marine Pollution, see OSPARCOM (1994); but also see the work of Bomans *et al.* (1996*a*); Brouwer *et al.* (1994*a*); Follett (1995); Lander and Moffitt (1996); Leuck (1993); Moon and Selby (1995); Schleef and Kleinhanb (1994); Shaffer (1995); Sharpley (1995); and Tunney (1990).

15. For details of the OECD Pesticide Forum see Grandy and Richards (1994), and for studies related to measuring agricultural pesticide use see Antle and Capalbo (1991), Brouwer, *et al.* (1994*b*); Narayanan (1995); OECD (1993*b*); US Environmental Protection Agency (1995*b*); and Ward *et al.* (1993). For an overview of pesticide data in the European Union see EUROSTAT (1996). The issue of pesticide use and ozone depletion is examined in Marcotte (1996).

16. Aspects of agricultural water use described in this section are taken from unpublished notes on updating work on AEIs in Australia, as set out in Agricultural Council of Australia and New Zealand (1993), and draws on work by French and Schultz (1984). For a discussion of the water pricing issue, including irrigation water, see the Industry Commission (1992).

17. Possible water use efficiency equations include for irrigated agricultural areas (and possibly other intensive agricultural areas), using the equation: index of the total value of agricultural production in irrigated areas/ hectares of irrigated area/mm annual rainfall + mm irrigation water (French and Schultz, 1984); and also an equation being developed by Japanese researchers: E = Total water use – Non-renewable water use/Total water use, where E = Effectiveness/Sustainability of agricultural water use; Water use = Agricultural water use including use of groundwater water – tonnes; Non-renewable water use = Agricultural use of groundwater – tonnes (except the amount of water recharge through agricultural land).

18. In terms of measuring the flood prevention, sustainable water use and prevention of soil erosion attributes of the conservation of agricultural land indicator the National Institute of Agricultural Engineering and the National Institute of Agro-Environmental Sciences in Japan have begun an extensive research programme.

19. For sources related to agricultural soil quality see Acton and Gregorich (1995), Bomans *et al.* (1996*b*); Buckman and Brady (1969), and Warkentin (1995).

20. For literature related to the issue of agricultural water quality, see Cooman *et al.* (1993), Crutchfield *et al.* (1995), MacDonald and Spaling (1995*a* and 1995*b*), Sinner (1992), and Warren (1971). For the impact of agriculture on marine water quality see GESAMP (1990) and OSPARCOM (1994).

21. For an overview of the IPCC/OECD guidelines on national greenhouse gas inventories, which includes agriculture, see IPCC (1995), and for further studies on GHG measurement related to agriculture see Born *et al.* (1992); Phipps and Hall (1994); and Smith *et al.* (1995). A progress report on the IPCC/OECD/IEA Programme on National Greenhouse Gas Inventories is available from the Pollution Prevention and Control Division, Environment Directorate, OECD, Paris, France.

22. For a review of biodiversity indicators in general see Reid *et al.* (1993). On the subject of biodiversity more generally see OECD (1996*c*).

23. Much of the literature related to the issue of agriculture and wildlife habitats also overlaps with that on agricultural biodiversity and landscape issues, see endnotes 22 and 24 respectively, but see also Baldock *et al.* (1993); Brady and Flather (1995); Flather, Brady and Inkley (1992); Montgomery (1996); Office federal de la Statistique (1995), and Schamberger (1988).

24. For an overview of defining agricultural landscapes see Meeus (1993). In terms of literature on measuring the agricultural landscape issue by use of various economic non-market valuation techniques see for example the national studies by Adger and Whitby (1991) for the UK; Brunstad (1994) for Norway; Drake (1992) for Sweden; the Japanese Ministry of Agriculture, Forestry and Fisheries (1994) on Japan; and Pevetz, Hofer and Pirringer (1990), and Pruckner (1995) for Austria. A brief review of these valuation methods for externalities and public goods is provided in OECD (1994*c*). An example of a physical inventory of landscape features can be found in the UK Department of Environment (1993), but also see Poiret and Vidal (1994).

25. The systems approach to landscape is described in the Dobris Report Chapter 8 (pp. 172-189), see European Environment Agency (1995).

26. For an overall view on the farm management area see Dumanski *et al.* (1994); Hilary, Spearin and Culver (1995); and US Department of Agriculture (1989). With respect to *nutrient management* a seminar was organised by the UK Ministry of Agriculture, Fisheries and Food, in conjunction with OECD, in April 1996, to examine the development of agricultural nutrient management indicators as summarised in the report of the seminar: *United Kingdom Report on Agricultural Nutrient Management Indicators,* available from the Environment Protection Division, Ministry of Agriculture, Fisheries and Food, Nobel House, 17 Smith Square, London SW1P 3JR, United Kingdom. On *pest management* see OECD(1995*d*), and the World Wildlife Fund (1995). For *soil management* see Simmons (1991) and the UK Ministry of Agriculture, Fisheries and Food (1993). On *irrigation management* see UK Ministry of Agriculture, Fisheries and Food (1991). Finally, on *whole farm management* see the New Zealand Ministry for the Environment (1996).

27. For a discussion of cooperative approaches to foster sustainable agriculture see OECD (1997*b*).

28. For farm income data sources relevant to measuring the farm financial resource issue see OECD (1995*e*) and on measuring policy transfers see OECD (1996*a*).

29. For further details of the work on rural indicators in the context of the work of the OECD Group of the Council on Rural Development see OECD (1994*a*) and OECD (1996*d*).

30. The possibility of adjusting agricultural productivity indices for environmental externalities see for example Ball and Nehring (1994), and on constructing a sustainability index for agriculture see Heinonen (1993). Life cycle analysis is also being considered in some research to capture the broader aspects of agriculture in relation to the environment and sustainabilty.

31. Work on examining the predicative capabilities of AEIs in agri-environmental policy assessment is underway in Canada, for example, see Smith (1995).

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