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Indicators for sustainable agriculture – a theoretical framework for classifying and assessing indicators

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Indicators can be used for identifying, simplifying and quantifying agri-environmental aspects of sustainability. They offer us a way to proceed from the theoretical definition of sustainability to more practically oriented approaches. This study examines agricultural systems with a view to identifying the points and levels at which the sustainability of these systems can be assessed.

The agri-environmental indicators are presented within the Pressure–State–Response (PSR) framework. Although suitable for ecological indicators, this framework is not highly relevant for economic and social indicators, which were thus studied from a more general theoretical perspective.

As the concept of sustainability includes a number of different value-laden definitions, the setting of indicators should be seen as an ongoing re-evaluation rather than a technical process of measuring certain parameters. The need to refine the assessment methods was recognised in several subthemes of agricultural sustainability. A major shortcoming was found to be the lack of tools for evaluating qualitative phenomena such as landscapes and animal welfare. Likewise, in economics and the social sciences, much needs to be done to promote understanding of the interactions between these disciplines and environmental processes. Moreover, the basic framework of the assessments requires further examination, for instance, when interpreting the indicator results, when dealing with uncertainty and when seeking to identify cause-effect chains, even though these questions are no longer purely matters of indicator methodology.

Key words: agriculture, ecological sustainability, economic sustainability, indicators, social sustainability

Introduction

Abundant information exists on the interactions between agricultural production and the environment. The problem is how to analyse the overwhelming amount of information produced by multidisciplinary fields of science. There is a risk that some key points or even the wider view will be missed. Before it is possible to affect the sustainability of agricultural development, the essential features of the development have to be known. Indicators can be used as an assessment method aiming to identify and quantify the main

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issues of agricultural sustainability. The simplification and quantification is needed to enable a discussion on agri-environmental issues to be conducted between the multidisciplinary partners and within the institutions of society. The increasing commitment to the environment in agricultural policy has pinpointed the need to focus agri-environmental measures more effectively; indicators are therefore also needed for monitoring and assessing the effects of policy measures (MacGillivray 1995, Dahl 1997, Tucker 1997).

At the international level, the feasibility of developing sustainability indicators has been studied actively since the 1980s, but the need to monitor the progress towards sustainability has received proper recognition since the United Nations Conference on Environment and Development, held in Rio de Janeiro in 1992. The 1990s have witnessed efforts by several national and international organisations to develop appropriate environmental indicators (see, for example, MacGillivray 1995, Adriaanse et al. 1997, Moldan 1997, OECD 1997, World Bank 1997, EUROSTAT 1998, United Nations 1998). In Finland, the work of developing agri-environmental indicators was started by the Ministry of Agriculture and Forestry in 1995.

My purpose here is to identify points and levels at which the sustainability of agricultural systems could be assessed. Therefore I will look at agriculture from the ecological, economic and social points of view. The study is a contribution to *SUSAGRI* (Sustainable Development in Agriculture), a project seeking to develop specific agri-environmental indicators in the fields of landscape-ecology, economics, and regional and social sciences.

"Sustainability" is here defined the successful management of resources to satisfy human needs while maintaining and enhancing the quality of the environment and conserving resources (Gianinazzi and Schüepp 1994). The concept is understood as an ongoing learning process or a value rather than an exact scientific term. Moreover, the social and economic aspects are regarded as important as the ecological ones; thus there is an urgent need to find the means for a more holistic interpretation of sustainability (for more about the problematic concept, see, for example, WCED 1987, Helmfrid 1992, Salminen and Lohi 1993, Jokinen 1995, Kumpulainen 1995, Dahl 1997, Bryden and Shucksmith 1998, Smith and McDonald 1998).

As the concept of sustainability includes several value-laden and subjective issues and cannot be fully defined in purely scientific terms, we cannot make a final assessment of agricultural sustainability. The indicators should be seen as one way of collecting information for further discussion on subject and as an ongoing learning process. In that context, the relevant questions are: how can the issue of agricultural sustainability be divided into more detailed indicator themes and how can these issues be measured or assessed in the most accurate way? The drawing of conclusions about sustainability or unsustainability is a separate matter and cannot be judged on purely scientific grounds.

Indicators are here defined as parameters, that is, measured or observed properties, or as values derived from parameters via, say, an index or model. These provide managerially significant information about patterns and trends in the state of the environment and in human activities affecting the environment, and also about the relationships between such variables (Dappert et al. 1997). Note that the indicators will never be a perfect match to the problem itself; they can only reflect some aspects of the reality by the means of the chosen method and context (Dappert et al. 1997, Gallobin 1997).

Selection of indicators

The selection of indicators can be viewed as a process. First, the specific goals of the assessment and its overall framework have to be defined. The goals can then be further divided into subtasks and themes; these are more rigorously outlined and can be measured more objectively than sustainability as a whole. The process continues by comparing alternative methods for measuring the chosen themes (Abrahmsen 1996).

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Then the data are collected and the results interpreted. Finally, methods used have to be assessed as the studied phenomena are complex and frequently changing (Hardi 1997). Indicator setting is thus a continuous process in which the more relevant and specific indicators can be defined in the light of experience and feed-back. I shall examine these phases in greater detail below.

Setting the goals and framework for the assessment

The goal of the assessment and the meaning of the indicators have to be re-evaluated for each case individually. At both national and international levels, indicators are needed to support and refine policy- and decision-making in sustainability issues, the basic problems often being how to quantify and compare conflicting interests (Kruseman et al. 1996, Gallobin 1997). The importance of integrating environmental concerns has been emphasised in agricultural policies, too (e.g. OECD 1998). Global conventions and protocols call for reliable information to be available at the time decisions are made and again when the impacts of the decisions are monitored. Meaningful use of the indicators is, however, hampered by differences in culture and geography and also in information collection systems between countries and regions. We often have to be satisfied with data on averages and totals, and functional links to causal factors may remain largely unidentified (Tschirley 1997). Thus, for assessments of sustainability issues, whether at the national or international level, there is a clear need for standardised procedures for collecting and analysing data.

At local scale, there are more possibilities for matching the indicator measures to locally relevant problems. The meaning of the indicators can be found by promoting an exchange of information and discussion between people. According to Hardi (1997) participation in assessment processes is essential for ensuring the recognition of diverse and changing values. Tschirley (1997), too, exposes the human capacity to manage development processes through participatory and transparent approaches. He notes that, without human understanding and participation, even the best data fail to lead to sustainable development. An open process and transparency of the methods may offer starting points for discussion, even when the parties represent totally different interests.

The use of the indicators and the interpretation of results will also require a clear conception of the overall framework of sustainability. The basic conception affects the methodological and conceptual choices and thus also the results. A clear framework helps to coordinate the separate details and to highlight the components important for the whole issue of sustainability. An explicated framework is also a tool for assessing and developing the methodology.

Quality of the indicators

A number of studies have been conducted on the quality aspects of indicators (MacGillivray 1995, Abrahmsen 1996, Malinen and Keränen 1996, Gallobin 1997, Hardi 1997, Liverman et al. 1998, Moxey et al. 1998). Key factors to be taken into account in the selection of indicators are 1) the specification of the indicator subjects, 2) data, 3) the assessment method, 4) the usability of the results, and 5) the cost-effectiveness of the whole process.

The first step is to establish the relevance of the indicators and their specificity for certain phenomena. The phenomenon ‘agricultural load’, for example, can be measured in several ways. Appropriate indicators could be: measures of agricultural fertiliser use, the nitrate concentration in the leaching waters of the root zone or the load at the scale of the whole catchment area. Each of these refers to a specific aspect of the agricultural load. We therefore have to choose the indicator most appropriate for each situation (Dappert et al. 1997).

Essential features in terms of data are their availability, reliability and coverage. Changes can only be monitored if the data are updated at regular intervals. The data may either be quantitative or qualitative. In most cases, numeric data will be the most useful, numbers being particularly appropriate for measuring quantitative phenomena such as the amount of emissions or the use of pesticides. Anyway, exact numbers give an impression of accuracy and objectivity, even where uncertainty, data gaps and conflicting values exist. Quantitative measures may be problematic in efforts to assess qualitative phenomena such as animal welfare or the beauty of the landscape. Lowe et al. (1997) point out that the great appeal of numbers has limited the issues handled at the political level; actions are only recognised as politically important when numeric data are available whereas more qualitative phenomena are neglected.

The assessment method can be chosen in the light of the technical functioning and theoretical clarity of the method and its general acceptability by the public. Methods can be further classified as aggregative and nonaggregative. Aggregation is needed in efforts to describe large and conflicting environmental phenomena without too extensive data. Several multicriteria methods employing, for example, Decision analysis, the Ecoscarcity method and the Environmental theme, have been developed for compressing multiple information and prioritising objects in an organised way (Seppälä 1997). Monetisation of biophysical indicators has also been suggested as a means for drawing conclusions about overall changes in sustainability (OECD 1998). Data aggregation, however, always implies simplification of information and loss of some meaningful aspects of complex phenomena such as sustainability. Temporal and spatial variations, for example, are essential aspects of sustainability and are difficult to express with highly aggregated indexes. A correlation with one type of environmental damage may be positive with one kind of indicator, but other impacts, for example, economic and social, must be studied in other ways. Too narrow and aggregated indicators should be avoided, at least at the initial stages of monitoring (Tschirley 1997).

The fourth aspect is usability of the results. As the indicators are means of communication, the results should be presented as clearly as possible, in such a manner that they can be readily understood by people with different educational backgrounds and occupations. The number of parameters should therefore be limited (Dappert et al. 1997). Ideally, the indicators should also be fully transparent so that their meaning and significance can be grasped by users in terms of their own values (Gallobin 1997).

The final aspect is an economic one. The cost of producing the information should be justified by the benefits of the knowledge produced.

Interpretation of the results

Interpretation is the stage at which the measured data are placed within a framework and linked to the various aspects of sustainability. For example, the amount of nitrogen in leaching waters does not really tell us anything unless the whole phenomenon of agricultural load and its harmful impact is understood – to some extent nutrient leaching is even beneficial to an ecosystem. Special reference values have been developed to steer the interpretation and help us define the significance of the results (Tschirley 1997). These may be norms, thresholds, targets or benchmarks referring to the state deemed desirable by authorities or societal consensus. Other, less normative, standards and benchmarks have also been defined (Gallobin 1997).

The setting of reference values for environmental phenomena may be problematic, as knowledge of underlying agro-ecological processes is sometimes inadequate, and circumstances may vary markedly from one region to another. Problems have arisen, in particular, in efforts to make comparisons between ecological, economic and social phenomena of sustainability, which all have fundamentally different nature from one another.

Indicators can also be used to describe trends in changes. A difficulty here is that the monitoring period needs to be long enough, environmen-

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tal phenomena being subject to numerous short-term fluctuations due to the seasons, weather, etc. In many cases, the actual trends should have to be monitored over many years or even decades (Lowe et al. 1997). Interpretation is further hampered by the complex interplay of economic, social and environmental components, the spatial variation and the nature of the processes involved, whether cumulative or gradual (OECD 1997, Tschirley 1997). If we take these problems into consideration, treatment of uncertainty and assessments of data validity and reliability acquire key importance for the presentation of "facts" of agri-environmental relationships. If the interpretations, assumptions and uncertainties regarding the data are presented explicitly, the user of the indicator knowledge will be able to evaluate the significance of the above shortcomings (Hardi 1997).

Finally, the assessments and interpretations always include subjective elements, even though in the technocratic approach the indicators are presented as standardised and universal norms that are scientifically defined. Clearly the indicators cannot be treated purely as objective scientific facts, as they reflect a number of cultural approaches, political interests and other subjective characteristics of human systems (Moxey et al. 1998). We should, then, be asking whether the people affected by use of the indicators are involved in the process and whether the implicit values have been openly discussed.

Agri-environmental indicators

Classification of the indicators in this study

A method widely used for classifying indicators is the Pressure–State–Response (PSR) framework. The model used by the United Nations Commission on Sustainable Development (UNCSD) and the OECD, for instance, distinguishes three classes: 1. pressures on the environment from human and economic activities, 2. the state or condition of sustainable development, 3. society's response to changes in the pressures on and state of the environment (Mortensen 1997, OECD 1997) (Fig 1.). The UNCSD further applies the framework to social, economic, environmental and institutional categories (Gallobin 1997).

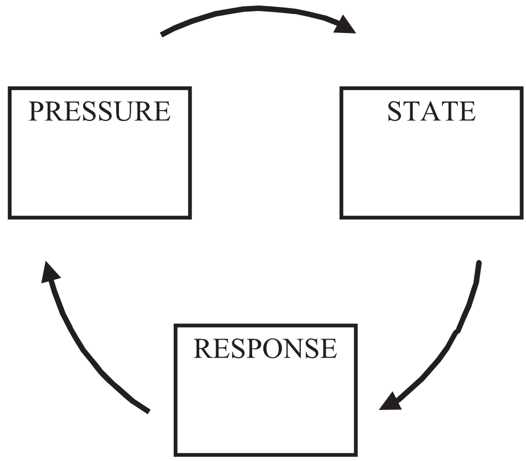

Fig. 1. Pressure – State – Response model (PSR).

Several improvements to the PSR model have been proposed. Regarding the terminology, it has been discussed whether "driving force" would be a more accurate term for the social, economic and institutional indicators than "pressures" (Gallobin 1997), whether "state" could be divided into impacts, effects and exposures, and whether "response" might be more appropriately termed "activities" (Billhartz and Moldan 1997). The main criticism of the model has been directed at its mechanistic world view and the assumption of causality between the pressure-state-response factors. It has been stated that the PSR model should not be treated as an analytical structure one, but rather as a taxonomy for ordering the indicators without any functional causality. Due to the complexity of sustainability issues, more advanced analytical methods would be needed to reflect the dynamics of sustainability (Gallobin 1997, Mortensen 1997).

Being quite simple and mechanistic, the model is, however, well suited to the ordering of agri-environmental indicators. Here, I use it to present the agri-environmental indicators relevant to Finnish agriculture. The economic and social indicators for sustainable agriculture are examined separately, as it is difficult in their case to make the distinction between the pressure, state and response dimensions. For example, the behaviour of the farmer could be understood as a pressure element for environmental change, as a state of environmental behaviour or as a response to changes in the environment. More flexible approaches are therefore needed to the economic and social processes guiding developments in society (Moxey et al. 1998).

In this study pressures include farm management practices and the use of resources, considering both as human activities affecting the environment.

The state indicators, soil, water, air and biodiversity, measure changes that have actually taken place in the bio-physical environment. Other relevant aspects of 'state' in agricultural production are animal welfare, the state of the landscape and the quality of products.

The response indicators measure the capability of society to provide responses to environmental problems through legislation, regulations, economic instruments and information activities (Mortensen 1997). The reactions of consumers and farmers, and changes in the overall agro-food chain can also be classified as responses (see, OECD 1997) but in this study, they will be considered in the context of social and economic indicators.

1. Farm management practices and land use

Information about farm management practices is not usually difficult to collect, as there exist official statistics on this subject. Land use, management practices, use of nutrients, pesticide use and water use have been suggested as relevant indicators (OECD 1997).

Information on the use of agricultural land describes the changes in cultivated areas. Management practices, e.g. fallowing, tillage methods, crop rotation, types of winter coverage or fulfilment of environmental protection actions, provide important, albeit often excessively detailed, information at the national or international level.

Nutrient use can be assessed through parameters of nutrient use per hectare, use of organic fertilisers, livestock density and biological nitrogen fixation. These parameters describe the extent and methods of agricultural nutrient use. However, in efforts to describe the risks of the nutrient load, a better proxy would be nutrient balance, as it provides information on net surpluses in agricultural nutrient use. Even the surpluses of nutrient balances do not ambiguously indicate direct environmental impacts, as they are not the only factors affecting the agricultural loading processes (OECD 1997).

Pesticides include insecticides, fungicides and herbicides. The problem with using data on them is that pesticides contain a large number of active ingredients varying in degree of toxicity, persistence and mobility and hence in environmental risk. Data on total pesticide use thus provide us only with rather rough information. The quantity of pesticides leaching into soil and water depends on several other factors such as soil properties, temperature, drainage, type of crop and application method (Abrahmsen 1996, OECD 1997).

Although information on agricultural land use and management practices appears to be clear and simple, interpreting it in terms of sustainability is complicated. Agricultural systems are highly complex combinations of technical, economic and biological processes and should be evaluated as holistic systems, taking into account local circumstances and needs for environmental protection. Measures sustainable in one area may cause considerable environmental deterioration in another. Environmental risks and values do not refer to individual farms but to production in a larger area. Evaluation of optimal agricultural practices should also take into account environmental outcomes that will be visible only in the long term or will impair the resilience of the system.

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2. Use of energy and natural resources
The goal of "eco-efficiency" calls us for a reduction in the use of natural resources together with more effective application and recycling of materials. The total use of natural resources can be assessed by material flows, that is, the physical quantities of material used in society. Hidden material flows (e.g. by-products and waste), which are not visible in a country's GDP, are also taken into account. It is now recognised, however, that material flow analysis needs to be able to take the quality aspects (e.g. the harmfulness of environmental emissions) of material flows into account as well (Adriaanse et al. 1997).

The use of materials and energy can also be specified at final-product level. Life Cycle Assessment (LCA) covers the cumulative environmental effects of a product throughout its useful life and includes the sum of resources required plus the amounts of waste and emissions (Stanners and Bourdeau 1995). More detailed environmental impacts are assessed by Life Cycle Impact Analyses (LCIA), which determine the actual amount of physical input or output. LCA and LCIA have, however, limited capacity to consider variations in time and space and the effects of the methodological choices on the results. These limitations are tried to handle by analyses of uncertainty and sensitivity (Nordic Council of Ministers 1995, Stanners and Bourdeau 1995, Seppälä 1997).

At farm level, analyses such as material flows or LCA would be too extensive; more appropriate indicators might be the proportion of recycled materials or the degree of self-sufficiency of the inputs (e.g. forage, energy, fertilisers).

The agricultural use of energy can be assessed 1) as the energy efficiency (or production of net energy) or 2) as a proportion of the renewable sources of energy used (e.g. hydro, solar and wind power; biomass including wood, ethanol from agricultural products, vegetable oils, and biogas from waste). The energy efficiency of primary production is calculated from energy production (energy generated in plant production) and energy consumption (e.g. fuels, manufacture of agricultural machines, buildings and fertilisers). The energy efficiency of the final products includes the use of energy in transport, processing, packing and marketing (Ministry of Agriculture and Forestry 1995, Abrahmsen 1996, Wahlström et al. 1996).

3. State of soil
Soil is a crucial natural resource for agriculture that provide a medium for plant growth, regulate wate flows in the environment and serves as an environmental buffer in the degdation of environmentally hazardous components. It is very important to protect the fertility of soil as rehabilitation may be extremely slow or even impossible. The state of soil is affected by three sets of factors: 1) chemical (pH, nutrients, heavy metals and other pollutants), 2) physical (soil type, texture and moisture, drainage) and 3) biological (flora and fauna in the soil).

The status of nutrients and heavy metals is studied by soil analyses (Erviö et al. 1990). Soil texture can be measured by volume weight, structure of soil aggregates, content of organic matter or amount of earthworms. Biological activity is measured by the existence of certain species or groups of soil flora and fauna, by microbial biomass or by analyses of the biological activity of soil micro-organisms. These are more difficult to measure than physical and chemical properties, but they may have also an advantages as early signals of soil degradation (Doran et al. 1994).

Although methods exist for estimating the status of soil, relevant data are scarce due to the expense and time consuming nature of collecting information on soils at specific sites. Methods based on modelling have therefore been developed for analysing larger regions. Such modelling enables the vulnerability of soil and the extent of soil degradation due to soil management practices to be assessed. These soil risk approaches do not reveal the extent of environmental damage but may suggest the degree of soil fragility in a region (OECD 1997).

4. State of water
The two main problems facing water protection

in agriculture are the nutrient leaching and erosion. Information on the contamination of water systems by agriculture can be obtained either by monitoring water quality or by modelling the factors affecting the agricultural load, as in the case of soil status.

Determinations of the impact of agriculture on water quality must distinguish between the agricultural and other sources of leaching. This can be done by monitoring either smaller catchment areas dominated by agricultural land use or larger catchment areas affected by other sources of loading (Stanners and Bourdeau 1995, Valpasvuo-Jaatinen 1998). The reliability of the results depends on the accuracy of the measurements and estimates of other sources and sinks of nutrients. Climatic fluctuations together with inter-annual variations and time lags in effects make it difficult for us to detect long-term trends in nutrient loads (Rekolainen 1993, OECD 1997). Other methods involving measurements of lake sediments or the abundance of micro-organisms in sediments have also been used to minimise the variation caused by changing weather conditions, but the problem of distinguishing the agricultural load from other sources of contamination exists here, too (Paasivirta and Känkänen 1998).

Assessments can also be made by modelling site-specific information on certain factors, e.g. land use, cultivation practices, water quality and erosion, and conditions in a catchment area. The information gathered will enable the critical source areas of erosion and nutrient loss to be identified and recommendations for reducing the load to be made (Dappert et al. 1997). The reliability of the models will depend on the quality of the original data, the conceptual underpinnings and the scientific soundness of the model (OECD 1998).

5. State of air

Greenhouse gases contributed by agriculture include carbon dioxide, methane and nitrous oxide. Agricultural emissions of carbon dioxide occur when soil organic matter is oxidised and affected by cultivation. Methane derives from ruminant livestock enteric fermentation and animal wastes and also from the burning of biomass. Nitrous oxides originate from fertilisers, animal urine, waste storage, biomass burning and fossil fuel use. There are also substantial emissions of ammonia from livestock and fertilisers (Stanners and Bourdeau 1995, Wahlström et al. 1996, OECD 1997). As well as producing emissions, agriculture acts as a sink of gases, and the net balances of release and accumulation are used for assessing its impact on the atmosphere.

6. Biodiversity

The state of biodiversity can be assessed at 1) genetic, 2) species and 3) ecosystem levels.

At the genetic level, it is essential to maintain the diversity of crop varieties and livestock breeds, bearing in mind the giant strides being taken in genetics and in breeding. Attention should also be paid to preserving traditional species, which are already excluded from agricultural production systems. These can be measured by the extintion of use of animal and plant species. Another important issue is the quality of populations, which can be assessed by measurements of effective population size (e.g. Kantanen et al. 1998).

At the species level, changes in the "key indicator" wildlife species residing in or close to agro-ecosystems are monitored. Such species may be either representative of a particular habitat or "endangered" or "threatened" with extinction in that habitat (OECD 1997). The former emphasises ecological sustainability in agricultural production itself, and the latter the overall meaning of agriculture for the protection of biodiversity. Several studies use bird and plant species, because they are relatively simple to identify and observe, and background information already exists about their ecology. Other possible indicator species include insects and various groups of fauna, although data on them may be more difficult to collect (MacGillivray 1995, Tucker 1997).

It would nevertheless be hazardous to draw conclusions from the changes in a particular species, for the changes may be due to a number of

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reasons. To overcome such problems, a range of species is frequently combined to indicate impacts of agriculture on biodiversity. Overall measurements of species richness and diversity can also be used (Wenum et al. 1997, Tucker 1997).

Biodiversity can also be studied through information on changes in habitats rather than through expensive and time-consuming field studies (Abrahmsen 1996, Ruuska and Helenius 1996, Tucker 1997). Analyses backed up by Geographic Information Systems (GIS) can produce information about the basic ecological circumstances and landscape ecological structures of an area. For example, changes in habitat shapes due to fragmentation, in the coverage of the habitats and in the lengths of their boundaries can all be defined by GIS and diversity indexes (Hietala-Koivu 1996). This information can be supplemented with more detailed field inventories and descriptions of the quality of these changes. The semi-natural habitats of agricultural landscapes, for example, can be assessed to have value as buffer zones, as areas maintaining the self-regulating processes of an ecosystem or purely as a source of scenic beauty (OECD 1998).

7. Welfare of production animals

Welfare, which should take account the individuality of the animals and the circumstances, is a highly relative issue. Efforts to define the status of animal welfare must consider physical and psychic aspects as well as philosophical and ethical goals (Castren 1997). Measures suggested for assessing are the following ones: 1) pathological, 2) physical or 3) behavioural approaches, 4) the production level of animals and 5) the production environment and method.

Pathological indicators such as mortality, morbidity and lifetime are clear and measurable parameters that give a general framework for assessing the condition of an animal. Physical measurements provide more detailed data on the reactions of an animal. Hormones and immunology are most often measured in studies focusing on the needs and requirements of the animal in general (Signoret 1983).

Abnormal behaviour (too aggressive or passive, tail biting) or stereotypical behavioural patterns may reveal physical or psychic suffering. As indicators, these symptoms of stress are complicated, because they should be interpreted as parts of a whole, experiences of stress and disturbance being also components of the natural environment of an animal (Castren 1997).

Because data on the above three indicators are difficult to collect at regional and national levels, productivity and detailed descriptions of production methods have been suggested as indicators. The description of the production methods may include several information such as the possibilities for natural behaviour and exercise, detail of the production environment, quality of fodder, treatment, management methods and social contacts with other animals (Castren 1997).

Production amounts have been put forward as indicators, because it is often claimed that a high production level reflects a high standard of welfare in animals. This argument may, however, turn out to be false in some cases, as an animal's production ability can be increased by restricting exercise or using hormones (Signoret 1983). Castren (1997) notes that production, e.g. of eggs or milk, is related to the most vital activities of animal regeneration; poor care of animals affects these activities only in the last phase.

8. Landscape

The landscape is shaped by ecological, economic and cultural interactions. Ecological features create the basic structures of the rural landscape but they, too, are largely influenced by human actions.

Most landscape analyses identify the ecological and human elements (e.g. Bastian 1991, Rautamäki 1997, Wascher 1997). A third element , time, creates the historical understanding to the landscape (Keisteri 1990, Forsius-Nummela 1997). The fourth element is the visual elements of the scenery (landmarks such as trees, linear features, and open and closed spaces).

All these aspects of the landscape are emphasised differently in different fields of science.

The natural sciences refer to landscape as a set of physical forms to be registered "objectively". The totality of the landscape is divided into different spheres, each one the speciality of a different discipline. The classification and evaluation of the landscape is then done by specialists. The human sciences see landscape as a subjective, value-laden experience of physical features in the human mind (Jones 1991). The significance of individual experiences and preferences is emphasised. Jones (1991) notes that the relative strengths of disciplines are time-dependent and that prevailing values will determine the current emphasis of landscape analyses.

Several approaches have been suggested for determining overall landscape indicators. Wascher (1997) identifies: 1) land use, 2) ecological structures and processes, and 3) cultural and scenic components. For these human components Wascher suggested the following measures: 1) coherence, all the functions and processes being irreplaceable parts of the unity of the landscape; the existence of harmony in time and space, 2) visual diversity based on natural or man-made elements of the landscape, 3) cultural identity based on, say, the locality or historical depth of the landscape, and 4) singular features perceived to be relevant to the human experience of scenic beauty. Also the OECD (1998) states that landscape indicators need to take account the natural, cultural and management elements that determine both the type of and changes in the landscape. Barrett (1992) stresses the integration of different aspects and proposes a Problem-Solving Approach, Net energy use and the application of GIS. None of these landscape indicator approaches has yet achieved dominance, and efforts to find the most appropriate one continue.

Interpretation of the results is also problematic. Every landscape is said to have intrinsic value. Moreover, the preferences of local people for developing their landscape may differ totally from the preferences of specialists and authorities (Forsius-Nummela 1997, Wascher 1997). Häyrynen (1997) notes that landscape preferences are never fixed, and change in response to the needs of society. Comparing landscapes in different areas and countries is also difficult. Certain features, say, the openness of the scenery, may be a dominant feature in one landscape area but totally irrelevant in another.

9. Quality of products

The quality of final products depends on the various steps in the food production chain: primary production, processing, transport, storage and marketing. The quality of food products is normally assessed by parameters such as nutritional value, contaminant content, hygienic quality, appearance and freshness. In terms of processing, technical features, too, are important. In addition to these objective aspects, most of which can be measured quantitatively, there are several subjective aspects that people may find more difficult to assess even though they consider them just as important. Examples are the effects of food on health, environmental impacts, preferences for products of local or domestic origin, and certain culturally-bound preferences. Quality standards and systems have now been developed to take such wider aspects of food product quality into account.

10. Public measures

Public measures can be assessed by both quantitative and qualitative approaches. The quantitative approaches determine the extent to which policy measures are carried out and the proportion of protected areas in a region. Such information is easy to collect and is relevant at policy level. However, measures such as the proportion of protected areas does not reveal the effectiveness of the measures (Tucker 1997); they may have been irrelevant or the means of fulfilment may have failed.

To assess the quality of the societal response, Benestad (1992) proposes three aspects: 1) cost effectiveness, 2) goal effectiveness and 3) dynamic effectiveness. Cost effectiveness measures how economically the objectives of a policy are reached, and goal effectiveness how well they are reached. Dynamic effectiveness considers the beneficial impact of the measures in general, that

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is, also outside the area for which they were specifically intended. In addition, policy measures can be evaluated in the light of technical functionality. The effectiveness of political measures can be compromised by short- term and internal contradictions within the political system, problems with disseminating the information, and a lack of confidence between different sectors of society (Valve 1995, Juntti 1996, Niemi-Iilahti et al. 1997).

11. Economic indicators

Economic indicators, which are already widely used in decision-making, play an important role in the workings of society. The conventional economic measures of profitability are relevant to sustainability, whereas environmental measures in agriculture need to be economically viable as well. Farmers need an income sufficient to allow them to take the environment into account in their management decisions (OECD 1998). For example, the rate of structural adjustment, the ability to acquire new technology, the application of environmentally sound production methods and responses to policy measures are all closely connected with economic development. Spedding (1996) even suggests that economic sustainability could simply mean, that if the agricultural systems are not profitable, they will cease to practise. The word "sustainability" could then be omitted, making it easier to discuss the issue of profitability as such.

Large numbers of parameters (net farm, average rate of return on capital employed or average debt/equity) have been established to measure the profitability of a farm. Future economic trends can be predicted by investigating changes in the number of farms and by looking at the rate of investment or number of generation transfers (Parris 1997, OECD 1997, OECD 1998). The profitability of farms is linked also to the economic development of the regions and to the viability of the sectors providing agricultural inputs and manufacturing food products. Thus, assessing the role of agricultural enterprises and their impacts on rural development could provide meaningful information at the local and societal scale of sustainability (Ploeg and Dijk 1995, Malinen and Keränen 1996).

Though there are plenty of economical indicators, the interpretation of the figures is far more complicated. What should be the preferred level of the economic indicators? Tisdell (1996, 120) suggests, that an economically sustainable system would be the one, which has a non-negative trend in total productivity. What is the level of farm income which will maintain the preferred amount of agricultural production and will allow the farmer also to take the environmental values into account, is not only economical but also a highly political question of society as Aakkula notes (1999). According this point of view, the question of farm incomes should be discussed also as a question of social sustainability and the farmers possibility to equal livelihood.

Many economists stress the need to address the environmental, social and economic aspects of development in a more holistic manner. The figures for profitability fail to take the quality of economic growth into account. Environmental degradation and the effects on the community tend to be neglected; the emphasis is on the short term, and thus inadequate attention is paid to the risks inherent in development or time preferences, both of which are essential in terms of sustainability.

Pearce et al. (1989) defined sustainability as a development endeavouring to maximise the net benefit of economic development while maintaining the natural capital over time. Thus, the use of renewable natural resources should be compatible with the rate of regeneration and the amount of waste that can be assimilated by the environment. The use of non-renewable natural resources can be sustainable only if the resources depleted can be replaced by the accumulation of other forms of capital (Hinterberger and Seifert 1997). The development is sustainable as long as the total stock of capital remains stable. Expressing of the environmental changes in monetary values is needed for to be able to measure the changes in total capital over time and to make comparisons between the various sources of the capital.

Such an approach has been used in the Green National Product, which is based on monetary aggregation. Other methods, such as Natural Resources Accounting is based on nonaggregated physical figures of change (Pearce and Warford 1993, Bergh 1996) In material flows an aggregation is made in units of kilos (Hinterberger and Seifert 1997). In the agricultural sciences, holistic analyses have been rare, and there is a clear lack of indicators seeking to show whether the profitability of agriculture has been achieved at the expense of the natural capital and will thus be unsustainable over time.

A more widely used approach for evaluating relationships between agriculture and environment in practical decisionmaking situations makes use of externalities. Producers or consumers do not have adequate incentives to consider the environmental effects of their decisions regarding resource allocation, because these effects are not reflected in prices (Drake 1994). Economic indicators could thus be formed on the basis of evaluations of the environmental benefits and costs of agriculture to give more relevant signals to consumers and other actors in the agribusiness. Expressing physical indicators in monetary form for decision-makers could be one way of addressing the trade-offs between economic and environmental phenomena (Pearce 1993, OECD 1998). The following are the methods most often used for monetary valuations: 1) maintenance valuation (estimating the costs of keeping the natural environment intact), 2) contingent valuation (assessing the stated preferences of people, e.g. willingness to pay) and 3) revealed preference (travel cost method, hedonic pricing method) (Aakkula 1993, 1997, OECD 1995).

The constraints on assigning monetary values to environmental phenomena and on setting prices for issues that do not have real markets have been widely discussed by economists. Aakkula (1993) points out three sets of problems: 1) philosophical, whether all nonmarket benefits can be expressed in monetary form, 2) methodological, e.g. the role of subjective values in methodological choices, 3) human, the reliability and validity of respondents' replies. Owing to these constraints, economic assessments of agri-environmental relationships must be supplemented by other measures of social and ecological development.

12. Social indicators

Social sustainability is generally understood within the framework of human welfare and the equality of its distribution. These are the aspects stressed by both the United Nations and the World Bank, with special reference to global sustainability (WCED 1987, World Bank 1997, UN 1998). Closely related are the approaches of Brown et al. (1987), who suggest that the social definition of sustainability might include the continued satisfaction of basic human needs – food, water, shelter – as well as higher-level social and cultural necessities such as security, freedom and recreation.

All these approaches highlight important human aspects of development but pay little attention to the relationship between human and environmental developments. Some researchers have therefore tended to stress the processes inherent in social sustainability, focusing on the manner in which society handles environmental issues. They assume that decisions regarding complex issues of sustainability do not depend on scientific calculation but ultimately on the resolution of different values through legitimate democratic and participatory systems. Problems cannot be treated as technical ones obscuring the social forces at work, though they are at the very heart of the problem of sustainability (Bryden and Shucksmith 1998, Moxey et al. 1998).

These approaches have been elaborated by the terms social capital and structural learning. The term social capital is broadly understood as the capacity of people to act purposefully and effectively so as to be able to cope with the threats and opportunities facing them; the exact meaning of this scientific term is, however, still under discussion (Bryden and Schucksmith 1998).

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The skills needed for building up social capital are not acquired merely through individual learning; they involve social learning, too. Lowe et al. (1997, also Moxey et al. 1998) use the concept structural learning, pointing out that the process of sustainability will be marked as much by changes in the interpretative frames of agricultural actors and institutional developments as by the physical outcomes of environmental management. Also Pretty (1995) emphasises the importance of human learning at the level of knowledge and values and also the interaction between different levels and participation.

In this approach, social sustainability can be defined as a process that enhances people's ability to control their own lives and reinforces their social identity (Rouhinen 1991, Rannikko 1997). According to Dahl (1997), the social and cultural processes that secure the transmission of knowledge and values to future generations are at the heart of social sustainability.

There are few social indicators proposed for agriculture so far. The OECD (1997) recommends that the following aspects be given further consideration: 1) consumer reactions, 2) agro-food chain responses (changes in technology, adoption of quality standards), 3) farmer's behaviour (changes in management practices, co-operation between farmers and other stakeholders) and 4) changes in government policy. Smith and McDonald (1998) draw attention to farmers and their managerial skills, mentioning educational level, skills, conservation attitudes and planning capacity as social indicators of agricultural sustainability.

However, the basic theoretical framework for assessing social sustainability and the criteria on which indicators are chosen have remained unclear. The many sectors involved in the agro-food chain – trade, politics, the food industry, agricultural research, education and extension services and the media – would also require more attention as social learning and the accumulation of social capital need to be evaluated at all levels of the food system.

Discussion

In this study I have sought to identify points and levels at which the sustainability of agricultural systems could be assessed. To start with I outlined the theoretical framework for comparing and selecting indicators. The aspects to be considered in the selection of assessment methods are 1) the setting of goals and the framework for the assessment, 2) the quality of the indicators and 3) interpretation. Quality aspects were further specified for 1) the relevance of the indicators, 2) the use of data and 3) assessment methods, 4) the usability of the results and 5) the cost of producing this information.

The classification of indicators was based on the Pressure–State–Response framework and supported by economic and social indicators. The framework was appropriate for environmental pressures, states and responses, but a distinction could not be made between pressures, states and responses in economic and social indicators. A number of approaches nevertheless exist for classifying indicators. The interacting agri-environmental phenomena can be divided into subareas and subthemes in many different ways. In each of these classifications there are some overlapping items of information and some gaps where information is concealed. Agri-environmental indicators were further studied to see how the information could best be used and to outline the restrictions to the interpretations on the basis of the theoretical framework.

Is it possible to assess agricultural sustainability with indicators? Defining the most appropriate indicators for agricultural sustainability is a highly complex subject involving interacting ecological, economic and social processes. In compressing large amounts of agri-environmental data into a few indicator parameters quite essential information is also loosed. Even so, indicators can present some facts and predict agricultural trends, which can be used as the foundation of further discussions of sustainability. Indicators offer us also a way to move away from theoretical and ideological issues of defining sustainability towards more practically oriented approaches.

The diversity of indicators presented here shows that indicators cannot be treated purely as technical data. The results are affected by several implicit or explicit choices that have to be made in the collection and processing of the data and also by associated values. Interpreting sustainability or unsustainability according to the conflicting results of ecological, economic and social indicators is no simple technical task. This stresses the importance of open discussion in which all the actors involved can take part together with the development of sustainability indicators as an ongoing process.

The use of information versus the cost of producing it needs to be evaluated case by case. Indicators are not the solution to every puzzle of sustainability; they could, however, be helpful in political decision-making and in the development of more effective administrative means. Another clear function for indicators in the future could be to provide more relevant information to consumers.

A large variation in assessment methods and data availability exists between the different agricultural disciplines. The assessment methods were easiest to define in the "traditional" fields of the agricultural sciences, though data availability may sometimes cause problems here, too. For example, the methods for assessing cultivation procedures and the state of soils and water, and for defining the objective quality of food products seemed to be technically functional and well worked out.

Assessing more qualitative phenomena such as landscapes and animal welfare is, however, more difficult. Though some tools have been designed for this purpose, the overall indicators are more difficult to establish. Economic data on agricultural profitability abound but in-depth knowledge of interactions between economic and environmental processes is still lacking. The greatest shortage of methods dealing with sustainability is in the social sciences, not even the theoretical basis of understanding the phenomenon has been defined. An assessment of the overall methodological base and the availability of data for agri-environmental indicators in the light of the conclusions drawn in this article is presented in Table 1.

In addition to the need to refine methods and improve the availability of data, the overall framework for evaluation requires further elaboration. There is a clear lack of tools for integrating different components, identifying chains of cause and effect, dealing with uncertainty and bridging data gaps. None of these issues, however, apply to indicator methods alone. Efforts must be made to develop interpretation as well; the data themselves will not contribute to sustainable development. We need more extensive and deeper understanding of sustainability as a whole and also new goals for sustainable development in agriculture.

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Table 1. Assessment of the methodological base and availability of data for agri-environmental indicators.

Sub-themes of agricultural sustainability	Methodological base	Data availability
1. Farm management practices		
– agricultural land use	***	+++
– management practices	***	+
– nutrient use	***	++
– pesticide use	***	++
2. Use of energy and natural resources		
– material flow analysis	**	+
– life cycle (impact) assessment	**	+
– proportion of recycled materials and self-sufficiency	***	+
– energy efficiency	***	+
– use of renewable energy sources	***	+
3. State of soil		
– chemical measurements, e.g. of nutrients, humus, pH	***	++
– physical measurements, e.g. of soil texture	**	+
– biological activity	**	+
– modelling of soil risk approaches	*	+
4. State of water		
– measurements of agricultural load	***	++
– modelling factors affecting agricultural load	**	+
5. State of air		
– modelling of agricultural emissions and sinks	**	++
6. Biodiversity		
– indicators at genetic level	**	++
– indicators at species level	**	+
– indicators at ecosystem level	**	+
7. Welfare of production animals		
– pathological indicators	***	+++
– physical indicators	**	+
– behavioural indicators	*	+
– descriptions of the details of production systems	**	+
8. Landscape		
– several approaches and methods	**	+
9. Quality of products		
– objective quality (e.g. nutritional value, contaminants, hygienic quality)	***	+++
– subjective food quality (e.g. effects on health, environmental impacts)	*	+
10. Public measures		
– quantitative measures of the extent of policy measures (e.g. proportion of protected areas)	***	+++
– qualitative measures of effectiveness	*	+
11. Economic indicators		
– profitability of agriculture	***	+++
– integration of environmental and economic knowledge	**	+
12. Social indicators		
– indicators of human welfare and equality of distribution	*	+
– social processes of sustainability (e.g. social learning and accumulation of human capital)	*	+

Methodological base: *** confirmed methods exist, ** methods exist, but without long experience or homogeneity, * some experience exists, but methods are still being developed. Data availability: +++ comprehensive information available at national level, ++some information at national level, + scattered data.

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SELOSTUS

Kestävän maatalouden indikaattorit – teoreettinen viitekehys indikaattorien luokitteluun ja arviointiin

Anja Yli-Viikari
Maatalouden tutkimuskeskus

Tässä artikkelissa selvitettiin kirjallisuuden ja teoreettisen päättelyn pohjalta indikaattorien soveltuvuutta maatalouden kestävän kehityksen arviointiin. Artikkeli liittyy Maatalouden tutkimuskeskuksessa meneillään olevaan monitieteiseen SUSAGRI-tutkimushankkeeseen (Sustainable Development in Agriculture). Tämän artikkelin tavoitteena on kokonaisvaltaisen viitekehyksen määrittäminen maatalouden kestävän kehityksen indikaattorien asettamiselle ja arvioimiselle. SUSAGRI-hankkeen muissa osuuksissa kehitetään ja testataan yksityiskohtaisempia indikaattoreita muutamille kestävän maatalouden keskeisille osa-alueille.

Indikaattorien tarkoituksena on tunnistaa ja kerätä laajasta informaatiotulvasta oleellista tietoa mm. poliittisen päätöksenteon, hallinnon, tutkimuksen ja kuluttajien käyttöön. Koska kestävän maatalouden käsite on vahvasti arvosidonnainen ja merkitykseltään monisisältöinen, ei indikaattorien avulla voida suoraan määrittää, mikä on kestävää ja mikä ei. Indikaattorit auttavat kuitenkin määrittämään kestävyyden keskeisiä alueita ja niiden tarjoaman tiedon pohjalta keskustelua kestävyydestä voidaan käydä moniulotteisemman tietopohjan valossa.

Artikkelin ensimmäisessä osassa selvitettiin yleistä teoreettista viitekehystä, joka liittyy indikaattorien valitsemiseen ja niiden käyttökelpoisuuden arvioimiseen. Maatalouden kestävän kehityksen indikaattorien esittämiseen käytettiin PSR-mallia (Pressure–State–Response), jota on käytetty useissa kansainvälisissä indikaattorien kehittämishankkeissa (mm. OECD, YK, EUROSTAT). Lisäksi selvitettiin indikaattoreita, jotka liittyvät kestävän maatalouden taloudellisiin ja sosiaalisiin ulottuvuuksiin.

Arviointi- ja mittausmenetelmät todettiin puutteellisiksi erityisesti kvalitatiivisiin ilmiöihin kuten maiseman laatuun ja eläinten hyvinvointiin liittyvillä kestävyyden osa-alueilla. Myös taloudellisten ja sosiaalisten indikaattorien määrittämiseen teoreettiset ja menetelmälliset valmiudet näyttävät vielä riittämättömiltä. Indikaattorien käytön yleisen viitekehyksen osalta todettiin kehittämistarpeita mm. tulosten tulkinnassa, epävarmuustekijöiden huomioimisessa ja eri osa-alueiden välisten yhteyksien tunnistamisessa.