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AGRI-ENVIRONMENTAL INDICATORS: LESSONS LEARNED AND FUTURE DIRECTIONS

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Indicators in time, space and multiple domains: lessons from applying an integrated assessment tool for agricultural systems
Sander Jansen, Researcher, Alterra - Centre for Geo-information, Wageningen, The Netherlands
Agri-environmental Soil Quality Indicator in the European perspective

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Soil quality is an account of the soil’s ability to provide ecosystem and social services through its capacities to perform its functions under changing conditions (after Tóth et al., 2007.) The concept of soil quality expressed by this definition allows practical applications with regards to targeted social and/or ecosystem services, including agri-environmental services.

The Thematic Strategy for Soil Protection of the European Union (COM 2006/231) identifies key soil functions of which the maintenance and improvement have to be considered in soil-related policies of the EU. Among the main soil functions several have agri-environmental relevance, which has to be taken into account when developing an Agri-environmental Soil Quality Indicator (AE-SQI).

For agronomic purposes the biomass production function of soil is of absolute importance. This function, however, can be performed under varying external influences. The two main factors conditioning the performance of biomass production of soil are climate and management. During the evaluation of production function, the reacting capacities of soil to these factors need to be considered.

Indication of soil quality from environmental point of view in the agricultural context can relate to off side environmental effects of soil condition and land management practices. The soil’s capacity to store, filter and transform substances is crucial in this perspective (e.g. carbon storage and climate change; buffering capacity and diffuse contamination). Soil biodiversity can indicate local environmental quality.

Based on the above concept an agri-environmental soil quality indicator is being developed for application in the European Union. The agri-environmental soil quality is expressed by an index constituted by four sub indicators:

- Productivity index (the capacity of soil to biomass production)
- Fertilizer response rate (input change / yield increase ratio)
- Production stability index (the soil-response to climatic variability)
- Soil environmental quality index (to express environmental aspects of SQ)

The four sub indicators cover both agronomic and environmental aspects of the goodness of soil (soil quality), therefore constitute to a comprehensive agri-environmental soil quality indicator, which might be applied on different spatial and temporal scales.

The proposed soil quality indicator can be used for policy development (including agricultural and soil protection policies) and monitoring through its capacity:

- to indicate the effect of land use change (marginalization; soil sealing etc.) on the availability and functioning capacity of soil resources;
- to indicate the effect of land management (e.g. intensification) on the functioning capacity of soil resources;
- to indicate the effect of climatic variability on the production function of soil resources.

Based on the information provided by the AE-SQI and its sub-indicators, current levels of soil agri-environmental services can be assessed, monitored and future levels of such services can be projected.
The ‘4R Nutrient Stewardship Framework’ links indicators of sustainability performance to policies and practices

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The 4R Nutrient Stewardship Framework—recently developed by the fertilizer industry worldwide—aims to provide context for sustainability reporting. Its implication for policy analysis is to require balanced sets of performance indicators encompassing social and economic areas as well as those related to the environment. In order to have policy relevance, it is important that indicators on the national and regional scale be meaningful, and actionable, at the farm level as well. The OECD 2008 report on Environmental Performance of Agriculture states “a key requirement of the indicators is that they adequately track developments that are of public concern, and are able to reflect changes in policies and farmer actions.”

The 4R Framework describes on-farm nutrient management practices with irreducible simplicity: applying the right source at the right rate, time and place (Roberts, 2009; Thorup and Stewart, 1988). The definition of the normative “right” is provided by the principles of sustainable development: optimizing the sustainability performance of agriculture, using indicators selected by its stakeholders (GRI, 2006). Universal scientific principles of nutrient cycles, soil fertility, and plant nutrition manifest themselves in specific management practices that vary with climate, soils, access to technology, local economies, and culture. The highest probability of meeting the goals occurs when science is applied to define a suite of practices from which farmers can select, using adaptive management.

This paper will explore the opportunity to link indicators to ground-level stewardship systems, ensuring valid analysis and evaluation of the impacts of policy on practices and outcomes.

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Ex-ante greenhouse gas balance of agriculture and forestry development programs

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EX-ACT (EX-Ante Carbon-Balance Tool) is a tool developed by the Food and Agriculture. It provides ex-ante measurements of the mitigation impact of agriculture and forestry development projects, estimating net C balance from GHG emissions and Carbon (C) sequestration. EX-ACT is a land-based accounting system, measuring C stocks, stock changes per unit of land, and CH4 and N2O emissions expressed in t CO2-eq per hectare and year.
The main output of the tool is an estimation of the C-balance associated with the adoption of improved land management options, as compared with a “business as usual” scenario. EX-ACT has been developed using primarily the IPCC 2006 Guidelines for National Greenhouse Gas Inventories, complemented by other existing methodologies and reviews of default coefficients. Default values for mitigation options in the agriculture sector are mostly from the 4th Assessment Report of IPCC (2007). Thus, EX-ACT allows for the carbon–balance appraisal of new investment programmes by ensuring an appropriate method available for donors and planning officers, project designers, and decision makers within agriculture and forestry sectors in developing countries. The tool can also be used to identify the mitigation impacts of various policy-strategy options for a region, a value chain or the whole agriculture sector and thus provide CO2 fixing targets as an additional criterion for policy monitoring, evaluation and analysis.

Agri-environmental indicators in sector models: the case of nutrient balances and biodiversity

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Agricultural sector optimization models have become a standard tool for farm policy evaluation. Traditionally, supply response and the quantification of welfare changes of different groups of the economy have been the major interest in farm policy analyses. The availability of a broad set of agri-environmental indicators and a better understanding of the causal relationships between production and environmental outcomes open the opportunity to construct models that can provide results not only on economic but also on environmental consequences.

The advantage optimization models have in integrated economic and environmental analyses over other methods are two-fold. First, it is possible to make ex-ante evaluations. Likely economic outcomes and environmental consequences can already be anticipated before a policy changes or a program is implemented. This helps to better target policies towards their intended outcomes because not only the reaction of economic agents is accounted for but also the environmental consequences of their choices.

Optimization models are advantageous even in ex-post analyses. If two events happen simultaneously – e.g. a change of market prices and the introduction of an agri-environmental programme – it is not possible to attribute a given outcome to only one event. In such a set-up a detailed bottom-up model is the only alternative to take account of different events causing observed outcomes and to explain in which ways the events interacted. Models allow to disentangle various pressures that have neutral, cumulative, or counteracting effects on the environmental state.

The integration of environmental variables into a farm sector model can be done in a straightforward manner when there is a direct link between farm inputs or farm outputs and an environmental indicator. Based on technical coefficients, indicators like nutrient-, energy- or CO₂-balances can be integrated into sector models by calculating them along with the levels of economic activity. This approach will be demonstrated by using the model PASMA of the Austrian agricultural sector which has a module that implements the OECD nitrate balance methodology. Owing to the structure of the model that allows to differentiate sub-regions and variants of farm management (organic and non-organic production) it is possible to provide a very detailed account of the status quo and various policy scenarios.

Several policy questions require an approach that to goes beyond this method to integrate environmental indicators in farm (sector) models. Typical questions are: In which way is nitrate concentration in groundwater affected after increasing/decreasing nitrogen surpluses of agriculture?
What are the consequences of changing land uses on wild species that use agricultural land as primary habitat? In order to answer such questions it is necessary to model the interaction of farm production and land use explicitly.

Two applications of the model PASMA exemplify this approach: expected changes of groundwater quality and expected consequences on biodiversity in an ex-ante analysis of the Austrian agri-environmental programme.

The link between groundwater quality and nitrogen balances is based on an econometric analysis of the link between nutrient surpluses and nitrate levels in groundwater samples. The effect of the programme on biodiversity is based upon the consequences of land use changes on representative species. For any of these species the habitat association was evaluated and scored (1, 2 or 3). Species with a score of 1 use the agricultural landscape regularly, but only during parts of their life and for some specific action, like foraging. Beyond that, they use a variety of other habitats and their dependence on farmland is rather limited. Species with a score of 2 depend on the agricultural landscape to a higher degree, but are not entirely restricted to agricultural habitats. Species with a score of 3 spend most of their life in agricultural landscapes and use agricultural landscape elements for breeding, foraging and hibernating. Land use changes are an output of PASMA and thus the likely consequences for the habitat availability for the different species can be evaluated.

➢ Towards indicators of landscape functions: from users expressed preferences to preference distribution

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The OECD list of agri-environmental indicators considers landscape functions (recreation, cultural identity) and landscape values as part of the landscape indicators that should be considered. Both should express the social value of landscapes. Social indicators are highly demanded for a complete and all-round evaluation of sustainability, but still little developed due to the difficulties in achieving reliable and replicable methods. Methodological developments are required here. Further, for many rural landscapes, in Europe particularly in the Mediterranean, the possibility of measuring their value as providers of amenity functions, e.g., public goods and services, may be the required way for securing their maintenance. This may be done through well calibrated public policies but also through the creation of new markets, and for both, knowledge on the value of the landscape is needed, as well as indicators that may express this value and its changes according to changes in the landscape composition. Again, the development and testing of new methodological approaches is required.

In this paper, we will present the results of research that aims at relating preferences, as expressed by different users, to the land cover distribution, and to express these relationships through selected indicators. These indicators should make it possible to measure how the amenity value of the landscape, for selected functions, changes according to variations in the land cover composition, as result from land use systems and practices. The focus of the paper is on the design of the methodological tool and the types of results produced, for a region selected as case-study. Preference data has been collected in the region of Alentejo, through a survey to different groups of users, linked to the most relevant and already acknowledged amenity functions. In order to reduce the confusing effects of landscape fuzziness, and to allow for linkages with available land cover data, the survey considered each of the land cover classes that are part of the Alentejo landscape, and besides selecting the preferred land cover class, the enquired were also asked to create their preferred landscape composition. This data allows for assessing the distribution of preferences, and to classify land cover
classes and proximity in between patches. This can in turn be related to the real or simulated land cover pattern, which can be classified according to the preference distribution, by user group. The effects in landscape amenity provision, of different scenarios affecting land use and land cover distribution, can also be measured, and thus scenarios can be compared.

- Developing an integrated monitoring system to assess agri-environmental measures effectiveness in Tuscany

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The rationale of the method proposed to monitor agri-environmental measures is based on a revised version of the methodology on how to develop effective, scientifically and economically verifiable local Agri-Environmental Measures (AEMs) developed by the AEMBAC project1 (2001-2004) of the EU 5th Framework Programme (Contract Ref. QLRT-1999-31666) (Riccardo Simoncini et al., 2004, How to develop effective agri-environmental Measures, IUCN, Cambridge Publications Services Unit, U.K.).

The overall objective of the AEMBAC methodology was to set up the design and development of agri-environmental measures (AEMs) that ensure the effective conservation of biodiversity and the environment by improving the sustainability of local agricultural practices.

In order to monitor and assess the effectiveness and efficiency of agri-environmental measures the proposed approach will focus on two sets of indicators and on the analyses of their relationships as defined by the AEMBAC analytical framework. These indicators describe:

- the state of each agro-ecosystem and its ability to perform selected environmental functions for the delivering of environmental goods and services;
- the local agricultural land use and practices; and
- the impacts that agri-environmental measures exert upon the ability of agro-ecosystems to deliver environmental goods and services.

The proposed method develops in a process of sequential steps that start with the identification of real or potential environmental functions performed by agro-ecosystems and the selection of indicators with which to analyse these functions. These indicators are then used to identify the Environmental Minimum Requirements (EMRs) for the successful performance of environmental functions and, in reference to these, to analyse the sustainability of the impacts of local agricultural practices in terms of delivering environmental goods and services. By factoring in the analysis the results (ex-ante, midterm and ex-post) of agri-environmental measures in lessening/eliminating agricultural negative impacts or improving positive ones, it is then possible to monitor and assess the effectiveness and efficiency of agri-environmental measures in enhancing delivering of environmental goods and services at the end of their implementation period.

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1 A detail description of the AEMBAC methodology is in Riccardo Simoncini, (2009), Developing an integrated approach to enhance the delivering of environmental goods and services by agro-ecosystems, in Journal Regional Environmental Change, Volume 9, Number 3 / September, 2009, Special issue on Rural Areas: Assessing sustainable options for multi-functional use of rural areas; Guest editors: Riccardo Simoncini, Rudolf De Groot, Teresa Pinto Correia, Publisher Springer Berlin / Heidelberg ISSN 1436-3798 http://www.springerlink.com/content/103880/
This process enables objective analysis of the effects of agro-environmental measures on the environment by the identification of scientifically and economically justified agri-environmental goals and, ultimately, the monitoring and assessment of effectiveness and efficiency of agri-environmental measures in achieving those goals.

Using a Beneficial Management Practice (BMP) Adoption Index in Agri-Environmental Policy in Canada

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Canada’s agri-environmental indicators provide an assessment of the risk of agricultural activities to the environment by using models to integrate biophysical information such as soil type, climate, and topography with land use information. Understanding the risk to the environment is essential to target areas needing attention and developing agri-environmental policy and programs to mitigate it.

The environmental performance of agriculture is largely influenced by the practices implemented on farms. Canada collects information on farm management practices through surveys, however until now it has been a challenge to organize this large amount of data in a way that is easily integrated into policy.

A beneficial management practices (BMP) Adoption Index has been developed to fill this information gap and can be used in combination with the agri-environmental indicators to provide a more complete picture of agri-environmental performance and better inform policy analysis and development. The flexibility of the tool allows assessment of BMP adoption by geographic region and major commodity, and can also be integrated with socio-economic information to better understand drivers and barriers to adoption and target policy and program development accordingly. This paper will present examples of how this tool can be used in Canada to enhance agri-environmental decision-making.
Using Agri-Environmental Indicators in Decision-Making: Examples from Canada and Issues to Consider

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This paper describes several examples where agri-environmental indicators have been used to support decision-making in Canada. Examples range from complex analysis to support national policy on business risk management, to the development of decision-support tools for farmers, to assessing the international agri-environmental performance for marketing needs. Based on these examples, the paper presents some key lessons learnt and issues to consider in the further refinement and development of agri-environmental indicators and their use in policy.

Agri-environmental monitoring: Tool of evaluation and help in decision-making for the Swiss agricultural policy

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The Federal Office of Agriculture (FOAG) carries out agricultural monitoring in the three dimensions of sustainability. Regarding the environmental dimension, it uses agricultural environmental indicators, by means of which it wishes to assess how agriculture affects environmental quality and how changes in agricultural practice affect the environment. This monitoring also shows areas where problems already exist or are emerging.

Also, agro-environmental monitoring enable us to measure the achievement of environmental objectives for agriculture.

The results of this monitoring, supplemented by general statistical data on the agricultural sector and results from special research projects (e.g. evaluations), constitute the basis for policy makers for assessing and developing agricultural policy instruments.

The results obtained by environmental monitoring are not only an important basis for political decision-making, but can also be used for international comparisons (benchmarking) and informing the general public on the interaction between agriculture and the environment.

The FOAG agro-environmental monitoring currently provides national information on the effects of agricultural practice on the environment and information on the state of the environment. To improve the support for decision-making, the monitoring is being regionalised.

In the medium term, it is envisaged to create links between the sets of economic, ecological and social indicators with a view of providing better insights into the interrelation between the three dimension of sustainable development.
Due to the large share of the EU surface occupied by agriculture, the role of agricultural activities goes beyond food production and involves a range of by-products that include the creation and maintenance of cultural landscapes and the provision of specific habitats.

Traditional agricultural practices, in particular, have created through the centuries specific environments that have supported large part of European biodiversity. Such environments have undergone deep transformations in the last 50 years due to the intensification of farming practices, which have contributed to the loss of biodiversity Europe is experimenting.

With reference to agriculture, when analysing the causes leading to the loss of specific habitats, two elements can be taken into consideration: farmland structure in terms of organisation of land cover types, and farming systems as the main driving force governing different land management types. Currently, a number of indicators are available to monitor the impact of agriculture on the environment, but what is also needed is a way to perform ex-ante impact assessment of policy scenarios, in order to support the steering of policy implementation towards sustainability goals.

A common pan-European indicator to evaluate the likelihood for an agricultural system to support biodiversity must assess those fundamental characteristics which are common to all or at least the vast majority of farming systems considered as potentially supporting biodiversity. Furthermore, in order to allow for forward looking impact assessment, the indicator must be based on such data where changes can be projected into the future as well as simulated depending on variations in policies or market conditions. The latter adds a rather stringent restriction to its development compared to monitoring activities where needed parameters can more easily be measured. However, in policy impact assessment, it is necessary to assess how changes in the farming systems driven by policy changes impact on their contribution to biodiversity.

The CAPRI (Common Agricultural Policy Regionalised Impact) modelling system offers the frame to perform this type of assessment, since it is structured in modules dealing with farming decisions at the level of individual EU27 regions plus Norway and Western Balkans, and links them to developments in EU and global markets for agricultural primary and secondary products based on global agricultural trade model. Simulation results cover prices, quantities of production, processing, feed, human consumption and trade of agricultural products as well as typical elements of an economic analysis as changes in agricultural profits, purchasing power of the consumer or the costs of running the policy. The model covers different environmental indicators as nutrient balances or Green House Gas (GHG) inventories.

The paper presents an operational methodology to calculate an indicator to assess the likelihood for farming systems at a EU-wide scale to support biodiversity, based on existing data and on an economic simulation model for agriculture, in order to provide policy makers with a tool to analyse policy scenarios. An analysis of the possibilities offered by such an approach but also of drawbacks and limitations is presented.
The Approach of the German Pesticide Risk Indicator SYNOPS in the Frame of the National Action plan on the Sustainable Use of Plant Protection Products

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A set of pressure, state, impact and response indicators has been suggested to measure the progress in reaching the targets of the German National Action Plan (NAP) on the Sustainable Use of Plant Protection Products. Among them the risk indicator model SYNOPS is used to assess trends of the terrestrial and aquatic risks of pesticide use in agriculture.

The indicator is applied on different levels of aggregation:

- To assure the tracking of the risk trends and risk development on national level, SYNOPS is used on yearly basis with annual sales or - if available - use data of pesticides assuming realistic worst case scenarios for the environmental conditions (SYNOPS-Trend).

- For regional risk analysis and the provisional detection of hot spots SYNOPS is used together with field based surveys on pesticide use and extended GIS based datasets on land use, slope, soil types and climate (SYNOPS-GIS).

The overall goal of the German NAP is a reduction of risks associated with the use of agricultural pesticides by 25\% in relation to the risks calculated for a reference time period from 1996 to 2005. To characterize the status quo, SYNOPS evaluated the risks of the pesticides sold in the crop years 2006, 2007, and 2008 in relation to the average risk of the reference period. Within the three considered years, a reduction of the terrestrial ($\delta ETR_{\text{ter}}$) and aquatic risk ($\delta ETR_{\text{aqua}}$) according to the goal of the NAP (25\%) was already assessed for Herbicides ($\delta ETR_{\text{ter}}=32\%$ and $\delta ETR_{\text{aqua}}=34\%$) and Insecticides ($\delta ETR_{\text{ter}}=61\%$ and $\delta ETR_{\text{aqua}}=44\%$) whereas the risk reduction for Fungicides ($\delta ETR_{\text{ter}}=24\%$ and $\delta ETR_{\text{aqua}}=17\%$) was still below this goal. For the future it has to be evaluated, if this trend remains.

A more detailed analysis of risks on regional level is accomplished with the GIS based version of SYNOPS. It relies on a GIS database, which includes all necessary environmental parameters on field level to estimate the exposure. The database was established by merging information from an extended geographical dataset (ATKIS), a digital soil map, a digital elevation model and a set of 430 climate stations (DWD). Regional data on pesticide use for the main crops are available from field based surveys.

In a study SYNOPS-GIS was applied to analyse pesticide risk trends in German orchard growing regions. The risks were calculated for all orchards within the regions. These results are expressed in risk maps and are the basis of identifying regions with higher risks. The impact of pesticide specific buffer zones and drift mitigation measures on the environmental risk is shown on regional scale. In combination with repetitively conducted use surveys for orchards in 2001, 2004 and 2007 the trend of regional risks could be analysed.
Australian agriculture faces a range of interacting forces. It farms challenging landscapes (water and nutrient limited; high levels of vulnerability to degradation), relies on global markets, is subject to both climate change and the actions needed to mitigate climate change, and seeks to maintain profitability and sustainability through a constant increase in productivity.

Australian natural resources audits and productivity analyses suggest both that the challenge is tightening – and that the information to observe the dimensions of the struggle and to design potential solutions is limited.

Here we consider different dimensions of these information sources (indicators in the broadest terms) and the interaction with policy designed to equip agriculture for a sustainable future in Australia. We consider the following programs:

- **Caring for our Country** – a major national investment which has evolved from a series of Government / community based approaches all of which have sought to foster sustained change to land management practices. The latest iteration has developed clear targets for investment and expected changes in soil condition and landscape biodiversity – dependent on quality information in setting the targets and evaluating performance;

- **Signposts of Australian Agriculture** – a formal approach to measure the performance of agricultural industries – presenting and integrating available information in terms of physical, economic and social outcomes;

- **Environmental reporting / accounting** – a group of activities including the formal State of Environment reports, which measure environmental sustainability in terms of the pressure, state and response of environmental indicators;

- **Productivity analysis** – a set of economic and biophysical measurements of total factor productivity, potential and achieved production;

- **Land use trends** – a set of national and collaborative activities which monitor land use, land use change and predict land use trends with likely policy settings.

These programs / activities respond to one or more aspects of the challenge to Australian agriculture. The paper explores important features of each of these, especially the interaction with policy settings and the sensitivity to the quality of current and evolving information systems – and to the capacity to assess status and trends.

Then the paper develops a view across these programs – illustrating the interaction and dependence between ecological sustainability and productivity outcomes, the importance of the spatial arrangement of land use practices and the changes emerging. The paper will discuss some of the lessons learned by Australian policy makers, desired features of an agri-environmental information system and recommend future directions for the OECD’s agri-environmental indicator work.
Soil Nutrient Balances – reviewing and developing to meet customer needs

Dave FERNALL
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Background

A methodology for calculating soil nutrient balances has been developed by OECD and adopted by Eurostat. Soil nutrient balances provide a method for estimating the nutrient loadings of nitrogen and phosphorus to agricultural soils. Whilst a shortage of nutrients can limit the productivity of agricultural soils, a surplus of these nutrients poses a serious environmental risk. Losses of nutrients to the environment can impact on air quality (ammonia emissions), water quality (N & P levels in rivers) and climate change (nitrous oxide emissions).

Defra (Department for Environment, Food and Rural Affairs) received funding under Eurostat’s TAPAS programme to review and develop the soil nutrient balance methodology. The project was broad in scope and aimed to:

- assess the overall approach
- evaluate the effectiveness of the current methodology and spreadsheet system
- check the quality of the data currently compiled for the UK estimates
- improve the overall reliability and presentation of the balance estimates

Conclusions

The key conclusions from the project were that the current methodology:

- Provides reliable estimates of the overall environmental pressures from nutrient loadings to agricultural soils
- Provides a robust, holistic approach that accounts for the full range of relevant factors (livestock rearing, crop and forage production, fertiliser use, manure management).
- Does not estimate the loss pathways of the nutrients
- Estimates total annual loadings but not cumulative or long term impacts
- Does not account for certain factors/practices that affect nutrient levels (animal housing, feed regimes, manure application methods)
- Uses a range of coefficients that need particular attention in terms of management, updating and documentation

Recommendations

There is scope to link the data system used for soil nutrient balances with similar systems in related areas. Much of the data is common to different systems and linking systems would allow more efficient use of this data and provide consistency across outputs for the systems. The most important of these is the IPCC greenhouse gas emissions inventory but other areas include national Nitrogen and Ammonia budgets, use of manures in biogas and anaerobic digestion and use of agricultural soils as a sink for sewage sludge.
There is scope to improve the reliability of some of the components of the UK balances, in particular for: offtake from pasture; regional estimates of fertiliser use; defining the land in scope; and assumptions underlying the estimates of manure.

At national level the results are robust and provide a high level measure of environmental pressure and an effective indicator of overall trends. At finer geographic scales (e.g. regional level) results are less reliable but can best be presented as a map or change matrix.

Ideally, results should be produced for geographic units relevant to policy needs for example river catchment.

➢ Use of Remote sensing for the Assessment of Farmland Biodiversity

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In many countries farmland represent the most relevant type of land use. The conservation and the enhancement of biodiversity within these areas is primary objective for the achievement of sustainable management of agro-ecosystems and the level of biodiversity can be used as agric-environmental indicator. The measure of biodiversity over larger territories however, can be very expensive and time consuming.

Earth observations have a rich history in characterizing and monitoring biodiversity and ecosystems. The possibility to use remotely sensed data for monitoring biodiversity was identified at the dawn of Earth observations and has been widely used for decades. Remotely sensed data can cost-effectively track changes in ecosystem distribution and status. The new generation of high-spatial and spectral resolution offers more hope for more direct monitoring of habitats and species.

Recent developments in satellite remote sensing and in geographic information system (GIS) combined with user oriented computer programs allow us to use ecological principles for biodiversity characterization at landscape level more efficiently.

This paper presents an approach for biodiversity characterization at landscape level using geospatial techniques. The present study hypothesizes that the complexity of the landscape is related to biological phytodiversity, and in turn phytodiversity can be considered a proxy of the overall biodiversity. The aim of the study is to estimate the farmland landscape complexity by using a remote sensing based approach. The approach has been validated in a Northern Italian agricultural area (Emilia-Romagna region).

The proposed approach can provide policy makers and land use planners valuable, updated and low cost information on farmland landscape complexity and an estimate of its biodiversity.
Crops and therefore food and feed production require an adequate supply of nitrogen (N). For sustainable agriculture efficient N use is a major task to ensure economically and environmentally sound food production. To minimize the impact on ground and surface water quality by increasing nitrate (NO3-) or the emission of trace gases such as nitrous oxide (N2O) and ammonia (NH3) the EU Nitrates Directive (ND), Water Framework Directive (WFD) as well as the Directive on National Emission Ceilings (NEC), set targets to reduce water and air pollution with agricultural N emissions as an important pressure point. The PARCOM and HELCOM agreements protect the marine environment. In Germany the Water Management Act is the national implementation of the WFD, while the national implementation of the ND is the fertilizer ordinance (FO). Therefore, the legal basis for agriculture production in Germany is the FO 2007 outlining principles for good agricultural practice, which is implemented in different regulations for the ‘Länder’. According to the NEC Directive, NH3 emissions from the farm sector have to be reduced in order to abate eutrophication and acidification and to limit negative effect on soils, forests and biodiversity. They are also relevant for the formation of particulate matter, while N2O is an important greenhouse gas from agriculture. Due to the overall importance of N emissions, the German national sustainability strategy sets the target of 80 kg N surplus per hectare utilised agricultural area in 2010. According to ND Germany has to report on the implementation of the national action programme, including the N balance indicator and the NO3- in the groundwater. The last report (Nitratbericht 2008) shows an improvement of water quality.

To identify where and to what extent nutrient surpluses or deficits occur, the gross nitrogen balance was developed as an agri-environmental indicator. For the national level the OECD recommends the gross soil surface balance, but in Germany also the farm gate balance is used by policy makers, e.g., for the sustainability strategy. Such balances are simplifications of complex and variable processes and therefore comprise a range of uncertainties. These uncertainties are mainly associated with either the statistical data base or the coefficient library used to convert the statistical data into N tonnages. The main input data influencing the N surface balance are the amount of mineral fertiliser (based on sales figures and not on the actual applied amount of N fertiliser), and the input from livestock manure (calculated from numbers of animal). The N output values are mainly driven by cereals, pasture and harvested fodder crops. A general major concern is the estimation of the pasture yields because of the large proportional influence of this output variable and the lack of reliable data. Whereas the yearly fertiliser and manure application are controlled by the farmers and based on average yield expectations, the subsequent yield depends on weather conditions and is therefore difficult to predict. Therefore, long term trends are more reliable than single or short term calculations, and are used as the basis for evaluating the achievement of policy targets.

For the regional WFD programmes the fertilisation ordinance is the core “basic” measure, while voluntary agri-environment measures are “supplementary” measures. In order to identify high risk areas of N pollution, regionalised N-balances are needed. Analysis of single farm- and farm group balances revealed a high variance of N efficiency within farm groups, highlighting the importance of adequate nutrient management. The German Systems of integrated Environmental and Economic Accounts (SEEA) also allow to derive product related input and emission values, based on input- / output analysis, and national N balances and gas emission inventories. The different policy targets
related to agricultural nitrogen emissions call for an integrated strategy to abate N emissions, and have to be supported with analysis of N use and the N flux at different levels.

➤ Gross Nitrogen Balance and Nitrogen Use Efficiency as tools for policy analysis and evaluation

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The gross nitrogen balance for the soil surface measures the difference between inputs as animal manure and synthetic fertilizer and outputs like crops, forages and grass consumed by grazing animals. The difference between input and output remains on the field and is potentially susceptible for losses to the environment. The nitrogen use efficiency is the ratio between the nitrogen output and nitrogen input.

Time series of both indicators can be analysed and evaluated for a specific country or area or between different countries or areas. Animal manure contains organic matter and minerals but the nitrogen in animal manure has a lower fertilizer value than synthetic nitrogen fertilizer. Nitrogen in animal manure deposited directly during grazing in the meadow has a very low nitrogen fertilizer value. So the share of animal manure in the total fertilizer input to the soil is important for the resulting gross nitrogen balance and nitrogen use efficiency. This means that changes in agricultural subsystems have to be taken into account when analyzing time series within and between countries.

The scale of gross nitrogen balances is important for the interpretation of the nitrogen surplus. Calculations for the EU15 and India showed for both continents 65 kg of nitrogen fertilizer input per hectare agricultural land and also for both continents a surplus of 60 kg of nitrogen per hectare agricultural land (calculations are done for the year 1998). It is evident that in both continents high nitrate leaching losses occurred with high nitrate concentrations. Gross nitrogen balances for large areas will level down locally high surpluses.

With no other changes in the agricultural subsystems both indicators are able to show the effect of policy measures like manure application techniques with low ammonia emission rates. These techniques prevent loss of ammonia to the air and thus more plant available nitrogen enters the soil. The accompanying savings on synthetic nitrogen fertilizer will lower the nitrogen input to the soil while the output remains the same. The surplus on the gross nitrogen balance will decrease and the nitrogen use efficiency will increase.

The uncertainty of both indicators depends on the uncertainty of the underlying components used for calculation of the indicators. Used amounts of synthetic fertilizer and produced arable crops are provided by national and international statistics. Animal numbers are also provided by national statistics and multiplying by nitrogen excretion factors per animal gives the total animal manure production. Estimation of forage production and direct grass intake in the meadow is difficult and subject to more uncertainty.

The paper will address the mentioned topics in more detail in order to facilitate the process of policy analysis and evaluation.
Grassland Conversion for Crop Production in the United States: Defining Indicators for Policy Analysis

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Agricultural land use change is a critical indicator of the potential for environmental damage from agricultural production. Shifting land from less intensive to more intensive uses—converting grassland to cropland, for example—may result in the loss of wildlife habitat, increased soil erosion and sedimentation, and higher levels of nutrient runoff and leaching to surface and ground water, respectively. Information on land use change, however, is not sufficient for analyzing the drivers of land use change, environmental outcomes, or mitigation policy alternatives. Analyzing policy alternatives to reducing land use change incentives, in particular, requires other indicators that facilitate understanding of the resource, technological, policy, and economic context in which land use decisions are made.

The conversion of native grassland for crop production has long been an issue in U.S. agricultural policy debates. In recent years, environmentalists, wildlife groups, and some livestock interests have become particularly concerned about the loss of native grasslands in the U.S. Northern Plains region. Native grasslands are important habitat for a number of threatened or at-risk species and, once lost, cannot be easily re-established. Locally, rates of grassland conversion of more than 2 percent per year have been measured. Concerned groups have focused on the role of federal programs that protect crop farmers from low prices and low yields by providing commodity payments and heavily subsidized crop insurance. The role of these programs, however, must be considered in the context of the land resources available for conversion and underlying technical and economic changes that could also contributing factors in land use change.

Land use change results from a confluence of factors including the availability of land that is on the economic “margin” between grazing and crop uses and a shift in the relative profitability of land uses. The change can flow from technical, economic, or policy change. In some parts of the U.S. Northern Plains, better varieties of corn and soybeans increased the relative profitability of these crops, leading producers to shift from wheat and other crops to corn and soybeans in places on the margin of the Corn Belt. In some areas, where there are large acreages of relatively productive rangeland and pasture, the change may have also encouraged producers to convert grassland to cropland. Policy may also have played a role because some farm payments are larger for corn and soybeans than for wheat.

To illustrate, we develop a series of indicators for resource quality, technology, and policy. We use the indicators to define, compare, and contrast three distinct areas within the Northern Plains. Using data on land capability, land use, and cropping patterns, we choose groups where (1) grassland conversion has been small and corn and soybeans have long been the dominant crops, (2) areas where grassland to cropland conversion has been relative large, and (3) areas where grassland conversion has been small but wheat continues to be the dominant crop. We profile each area in terms of land available for conversion to cropland (1997), changes in cropping patterns (1997-2007), the use of genetically modified corn and soybean varieties (1997 and 2007), and size of farm program payments.
The use and influence of indicators in agri-environmental policy processes in Denmark

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It has been questioned if and how knowledge influences policies in intended and un-intended ways, and various types of evidence have been studied with this focus, such as evaluation (Weiss 1998, Henry & Mark 2003) and impact assessment (Hertin et al, 2009). Indicators have similarly been studied as one type of “knowledge agents” with intended, instrumental uses for policy making, which may, in praxis, be used, used in un-intended ways, used but with little influence on policies, or disregarded. It has been discussed what causes are for different use and influence pathways (Gahin 2003, Hezri 2004, Weiss 1999).

This is the background for a project under the EU 7th Framework Programme: POINT (Policy influence of indicators). Indicators and indicator sets studied in this project are sectoral indicators, sustainability indicators and aggregated indicators.

The present paper introduces shortly the common analytical framework and an analytical “scheme” focussing on emergence, use, influence and role of indicators, which has been developed in the project, based on an extensive literature review (Gudmundsson et al., 2009).

From this introduction we present the ongoing Danish case-study on agri-environmental indicators. The study sets out to explore to which extent policy processes in the agri-environmental policy area has relied on scientific knowledge in the form of indicators (at national level), and which role they may have played.

The analysis identifies the policies which are – intentionally - informed by indicators, i.e. mainly the agri-environmental part of the rural development policy and the aquatic environment policy. Key policy turning points are identified for the study period (2000 – 2009), and the emergence and institutional setting of indicators and indicator sets are described. Next, the intended information channels from monitoring programs to policy makers are analysed and indicator use as part of the overall knowledge production is explored for a specific policy situation leading to the agreement of the third action plan for the aquatic environment (2003). Eventually specific indicators are traced into other uses by other institutions and NGOs.

The influence of indicators in the policy process is discussed, and emerging hypotheses of indicator use and influence in the Danish agri-environmental policy area are proposed, including the importance of:

- the degree of structuring of policies (vis-à-vis Turnhout (2007));
- the degree of institutionalisation of environmental concerns into administrative structures, and
- the degree of environmental policy integration (vis-à-vis Weiss (1999)).

References


➢ Development of Agri-environmental indicators in Austria

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Sets of indicators are in use to monitor development in Austria. They were built along a framework allowing to focus on any area of interest.

There exist indicator sets for the monitoring of sustainable development, the environment and biodiversity. For all of them the development of indicators is shown in reports.

It will be presented how an indicator set on the relation between agriculture and environment can fit into the established framework. Steps necessary and what has to be considered when developing and implementing such an indicator set will be described.

➢ Agri-environmental indicators for biodiversity in the rice paddy landscape

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The OECD agri-biodiversity indicators need to balance the need to be comparable across the member nations, and yet provide useful ecological information about organisms, their habitats, and the agricultural practices that affect them. One approach to this problem has been to define key habitat concepts, including semi-natural habitats in farmland. Indicators need to define how specific habitats meet the definition of the key concept while remaining informative about the characteristics of each habitat. This is a particularly critical problem for the rice paddy landscape in Monsoon Asia, because key habitat concepts proposed in the OECD program often have been based on very different agricultural systems.
Rice paddy agriculture is important because it is the primary form of agriculture practiced in two OECD nations, as well one of the most widely practiced in the world. As noted in an OECD report, certain forms of rice paddies in Japan and Korea are examples of low intensity agro-ecosystems developed over hundreds of years that are key habitats for flora and fauna.

Recent projects in Japan on biodiversity and wildlife habitat analysis are working towards developing indicators, based on field research and GIS, to identify key habitats within the rice paddy landscape. The ultimate objectives are to (a) propose indicators for monitoring the effects of farm practices on the fauna and flora that find habitat within the rice paddy landscape, (b) more clearly define and identify semi-natural habitat within Japanese rural landscapes, and (c) targeting agri-environmental measures to areas where they can be most effective. These projects include the following:

- A critical character of rice paddy landscapes supporting large biodiversity is the close combination of wet paddy with a variety of other land covers that allows organisms using multiple niches to complete their life cycle. One form of long, narrow rice paddy surrounded by woodland is called yatsuta. GIS analysis to identify yatsuta is showing that they comprise a small proportion of rice paddies, but account for a large proportion of the contact surface between paddy and woodland because of its widespread, dendritic landscape configuration.

- The Rural Landscape Information System (RuLIS) maps Japan with a 1 x 1 km grid system based on a landscape classification with 60 classes, including yatsuta. By surveying fauna and flora in selected sample grids, RuLIS can identify the landscape classes that tend to support greater numbers of particular organisms, and model their potential habitats. So far, researchers have modeled habitat potential for butterflies, dragonflies, fishes, and frogs.

- Ornithologists are making progress in defining and identifying farmland bird species. They are finding that, similar to trends suggested by European data, some species of farmland birds have been declining in Japan, including some that feed in rice paddy environments.

- A research project has been started on functional biodiversity to identify indicator insect species among the natural enemies of crop pests to guide environmentally friendly farming.

➢ Nitrogen Use Efficiency as an Agro-Environmental Indicator

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The growing world population demands increasing food production. According to the projections of the United Nations Food and Agricultural Organization (FAO, 2006), the production of cereals will increase by 60% from 2000 to 2050. More crops require more plant nutrients. As a consequence also fertilizer consumption will increase considerably. Fertilizers are applied to balance the gap between the permanent export of nutrients from the field with the harvested crops and the nutrients supplied by the soil. However, not all of the applied fertilizer ends up in the crop. Part of the fertilizer nutrients are lost to the wider environment and contribute to environmental problems such as loss of biodiversity or climate change.

This is why society and policy ask for more efficient use of plant nutrients in agriculture. The United Nations Economic Commission for Europe (UNECE) currently revises its so-called “Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone”. Nitrogen use efficiency (NUE) will be a key indicator in this international convention in order to assess the efficacy of measures to decrease nitrogen (N) losses while maintaining agricultural productivity.
Nitrogen use efficiency can be defined as the ratio between the amount of fertilizer N applied and the amount of N removed with the harvest. However, different definitions of NUE have been proposed (e.g., Dobermann, 2007). Even more important than the way of calculation is the interpretation of the results. Examples from field trials show that very high as well as low NUE values represent unsustainable crop production systems and that the interpretation of NUE values requires a qualification scheme.

This study examines

- how NUE can be determined;
- the NUE of different N application rates in a long-term field trial;
- how these results can be interpreted and qualified; and
- the transfer of this approach to public available data on country or regional level.

Addressing the spatial resolution of agri-environmental indicators in Norway

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The Norwegian monitoring programme for agricultural landscapes (the 3Q Programme) was initiated in 1998 with the aim to quantify changes in agricultural landscapes and provide data to assess developments in relation to agri-environmental goals. 3Q involves detailed mapping of 1 x 1 km sample squares, based on the interpretation of true-colour aerial photographs (Dramstad et al. 2001). The sampling is designed such that the 1400 monitoring squares comprise a representative sample of Norwegian agricultural land. By combining 3Q data with various national databases, agricultural census data and the Norwegian Landscape Reference System, a range of indicators have been calculated, providing feedback to policy-makers at national and regional levels. The reporting includes biodiversity, cultural heritage, farm management and landscape indicators, and emphasises the links between these themes.

For biodiversity indicators at the species level, there is relatively little data available in Norway. Breeding birds have been recorded in the field at 130 of the 1400 monitoring squares, and vascular plants have been recorded in selected habitat types (grasslands) at 100 squares. This is insufficient to provide indicators at a regional level, but can provide a minimum of standardised information at the national level. Although more time steps are needed before we can analyse change, the state data for breeding birds show a clear positive correlation between the number of species of farmland birds and the area of agricultural land per square. This result reflects the relatively small-scale nature of agriculture in Norway and confirms the importance of agricultural landscapes for national biodiversity. The monitoring of bird and plant species is best suited for revealing trends in the occurrence of those species that are relatively common in today’s agricultural landscapes, but also captures information about threatened (red-listed) species and about invasive (black-listed) species. Importantly, gathering different types of information at the same monitoring squares provides an opportunity to validate other, more indirect, indicators of biodiversity, as well as enabling research into the driving forces of changes and the responses of species to agri-environmental schemes or changes in farming practices.

Biodiversity indicators at the habitat level are derived from the entire national set of monitoring squares. In practice, however, in a country as varied as Norway, some habitat types are specific to particular regions. An example is the indicator “number of farm ponds”. Farm ponds occur
in lowland agricultural landscapes, where they are important elements for landscape character, with aesthetical and cultural value in addition to their importance for biodiversity. The lowland landscapes are also the areas where cereal growing is concentrated, and farm ponds provide the valuable ecosystem function of protecting waterways from run-off from ploughed land by capturing nutrients and soil particles. Several counties have schemes within their Regional Environmental Programme to provide financial support for maintenance of farm ponds or establishment of new ponds. Although farm ponds may vary considerably in their quality as habitat, a decline in number is a clear indication of a negative change. This indicator can therefore be useful for comparing trends in the different regions that have farm ponds, and may provide feedback as to which Regional Environmental Programmes are most successful in preserving or increasing numbers of ponds. In other regions however, this indicator has no policy relevance. The situation is similar for other indicators that reflect both habitat occurrence and landscape character, such as the length of rows of trees, stonewalls and ditches and streams. Thus, whilst the monitoring system enables us to calculate all indicators in all regions, the relevance of the indicators varies from region to region. The results from the first inventory cycle of the monitoring programme were useful in illustrating these regional differences, and in some cases raised awareness within the regional management authorities and were used when formulating the Regional Environmental Programmes.

Of all of the indicators provided by the Norwegian landscape monitoring programme, the two that have been the most widely used and discussed, both by policy makers and in the media, are the area of agricultural land converted to built-up land and the area of abandoned agricultural land. These measures are linked to strong national political aims: to halve the loss of cultivated land to other land uses by 2010, to preserve agriculture throughout the country, and to increase grazing by domestic animals in order to maintain open landscapes. Agricultural census statistics show there has been a dramatic decline in the number of farms in Norway, from 70 000 in 1999 to 49 000 in 2008 or an average annual decline of 3.4 % (SSB). By 2008, 22 % of agricultural properties with residential houses were standing empty. Changes in indicator values over a five year period revealed land abandonment even in South Eastern Norway, in regions generally considered to be more at risk from urbanisation than abandonment.

In Northern Norway, scrub encroachment and reversion of agricultural land to forest are very obvious landscape changes that are well known to policy makers. Here, the usefulness of the indicators comes through combining different data sources to analyse the driving forces of change. Land ownership patterns were shown to have an important influence on the probability of abandonment, with rented land more likely to be abandoned than land that is farmed by the owner (Stokstad 2009). The probability of abandonment also increased the more distant a farm was from its nearest neighbours. It has been suggested that financial incentives to maintain current land-use can be most effective in remote areas of low productivity, where “a modest payment may be sufficient to maintain a farm in operation” (OECD 2009), whilst such payments “are not needed” in the agricultural core zone. We suggest that in Norway, due to the harsh conditions for agricultural production and the low population as a basis for alternative sources of income, payments may be needed in the core zone, but may be less effective in the remotest areas. Indicator data may be useful in modelling work to enable identification of remote farms at greatest risk of abandonment and clusters of farms that might have more chance of success if targeted in agri-environmental schemes.

To conclude, AEIs are being used for policy purposes at a range of scales. Spatial variation is taken into account by interpreting indicators in relation to landscape types and regional environmental goals. Importantly, analyses to identify driving forces of change and explore the relationships between different indicators are dependent on data at a very high spatial resolution, including both detailed maps of land use/land cover (sampling) and farm management data at the level of the farm (data from farm censuses and from the Applications for Subsidies Database). It is at this disaggregated level that AEIs are most useful for evaluating the effects of agri-environmental policy tools.
References


Application of agri-environmental indicators in Portugal

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1. Introduction

2. Development of agro-environmental indicators

3. Agro-environmental indicators as a policy tool
   a. Examples on the use of AEI
   b. Lessons learned and future needs

The development of agro-environmental indicators is presented briefly, focusing on the architecture of the process which makes clear the need for multiple expertises to deal with the complexity of the relationship between agriculture and the environment.

Some key situations regarding the use of agro-environmental indicators are analysed illustrating their importance as a policy tool. Will be presented also some ideas about the need both to improve the effectiveness of this tool, both the development of new specific indicators, always taking into account the balance between the cost of this improvement and their effectiveness on bringing to the decision process the particular aspects that are needed to be addressed by policy measures.

The ARMS: A Survey Supporting Indicator Development and Economic Policy Analysis

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The annual Agricultural Resource Management Survey (ARMS) is USDA's primary source of information on the financial condition, production practices, resource use, and economic well-being of America's farm households. ARMS is the only national survey that provides observations of field-level farm practices, the economics of the farm businesses operating the field (or dairy herd, green house,
nursery, poultry house, etc.), and the characteristics of the American farm household (age, education, occupation, farm and off-farm work, types of employment, family living expenses, etc.)—all collected in a representative sample.

ARMS data are collected at the individual field or production unit level (Phase II), and for the whole farm (Phase III). Field-level data include information on chemicals and seeds, equipment, previous crops, highly erodible land, irrigation, and pest, nutrient, and crop residue management practices. These data are useful for supporting the development of environmental indicators, calibrating economic models, and conducting economic analyses of polices that mitigate environmental quality and conserve scarce natural resources.

This paper describes the challenges associated with designing the ARMS survey instrument, scope of commodity coverage, specific information collected at the field and farm-level, examples of uses of ARMS for policy analysis, model calibration and indicator development, and some recent innovations made to the survey (e.g., linking the CEAP and ARMS, organic oversample, and geo-coding field level observations). Overall, the ARMS survey is shown to be a valuable and versatile source of national data to support economic research on farmers' decisions to adopt new technologies and to relate those decisions to the economic performance and structural attributes of farms and farm families.

Policymakers’ Priorities and Policy Linkage Using Agricultural Environmental Indicators in Korea

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Indicators are deemed as effective basic information which provides helpful tools for decision making when information is incomplete. In reality, indicators do not provide accurate and complete explanation on specific issues so they mostly play a subordinate role, not a leading role, in terms of decision making. Agricultural-Environmental Indicators (AEIs) are representative values that indicate the agricultural impact on the environment and the environmental impact on agriculture. In other words, they are the representative values of environmental elements (water, soil, air, etc.) of the agricultural eco-system. They are calculated based on certain criteria and explain mostly about the reality.

The objectives of this paper are to survey Korean policy makers’ using AEIs and to present cases of linkage and application analysis of agri-environmental policy in order to support effective decision making. Policymaking authorities including central and local governments are surveyed for the utilization of the AEIs such as land use, soil erosion, water quality and water use, biodiversity, nutrients, air, landscape, pesticide, and energy indicators. Five criteria such as understanding, necessity, utilization, contribution, and credibility are used in evaluating the AEIs. The questionnaires are responded based on the five-point Likert scale. The survey results will provide an idea as to which indicators in the policy inventory are valued and used by policy makers. In addition, the analytical results suggest the bottleneck for utilizing AEIs and the schemes for improving the AEI utilization. In addition, illustrated examples of policy linkage on AEI are applied to surplus nutrients management program like Regional-Based Maximum Nutrients Loading System and regional development planning based on material balance approach. The Regional-Based Maximum Nutrients Loading System at system is a decisive measure to find out the nutrient balance status by region and properly resolve the nutrient excess problems in Korea. Korean government announced its plan to introduce the system from 2007. The regional agricultural development planning based on nutrients balance will present Jinan county case in Jeonbuk province in order to establish regional environmentally friendly
Experiences in using AEIs as a regional agri-environmental programme policy tool in Norway

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The climatic and topographical conditions for agricultural production in Norway are very varied (temperature, precipitation, soil type etc). Most cereal production occurs in the South-East and in Trøndelag County, in the middle of the country. These areas have the best combination of soil and climatic conditions for cereal cultivation, however, the clay soils are susceptible to erosion and loss of nutrients. Animal husbandry occurs in Western Norway, mountain districts and Northern Norway, where the climate is colder, with more rainfall and conditions suitable for grass production and pasture. In the south west of the country, we have the most intensive animal production, with cattle, pigs and poultry. This causes problems of pollution to waterways in several areas.

Due to the regional differences in both production types and natural conditions, the environmental impact of agriculture also varies considerably within the country. This creates challenges when trying to find targeted and effective policy instruments, and in evaluating the effects of the policy measures that are applied. This also means that great care is needed when interpreting indicators of environmental state, and rather that indicators should be interpreted as a general expression of a development trend.

In 2005, Norway introduced a system of “Environmental Programmes for Agriculture”. The overall aim was to strengthen the environmental efforts of the agricultural sector. The Environmental Programmes include measures at both national and regional levels. The national programme sets a framework to ensure that national and international goals and commitments are fulfilled. The national program includes horizontal instruments that apply to all agricultural production throughout the country. The Regional Environmental Programmes are drawn up through an open process where challenges and problems are identified and measures set in place according to regional needs and priorities. Based on these priorities, regionally adapted policy instruments are established. The Regional Environmental Programmes address the following themes: cultural landscapes, biological diversity, cultural heritage, accessibility and recreation, run-off to waterways and use of herbicides and pesticides.

The issue of erosion and loss of phosphorus to waterways provides a good illustration of the challenges associated with great regional variation. Similar issues apply in relation to themes such as biodiversity or preservation of cultural landscapes etc.

In Norway, problems associated with phosphorous and erosion are more important than problems linked to nitrogen. The reason for this is that groundwater is seldom used for drinking water supplies. Loss of nitrogen is primarily linked to the risk of nitrous oxide (N2O) emissions.

To improve our knowledge of the environmental impacts of agricultural activities and to document and evaluate the effects of policies, a system of reporting and evaluation has been established. This system uses environmental indicators, measurements in the field and data from management authorities on the application of different agri-environmental instruments etc. The Soil and Water Monitoring Programme (JOVA) operated by the Norwegian Institute for Agricultural and Environmental Research (Bioforsk) is a part of this system. The programme measures the
concentration of phosphorous, suspended matter and agro-chemicals in water. Nine measuring stations are located such that they provide a representative picture of agri-environmental effects under different climatic and agricultural conditions. The results show great variation for different farming types, between different parts of the country and between years. The programme started in the 1990s and it is difficult to find significant trends that can be said to be due to the policy measures set in place. This can be illustrated using results from 2008/2009 from two areas that can be considered almost identical regarding crop type and management practices. Concentrations of suspended matter (SM) and phosphorous (Tot-P) differed by more than 100 percent between the two areas. Important factors influencing run-off have been very similar in the two areas, but the differences can be explained by differences in soil type. This illustrates the challenges involved in defining and delineating appropriate units for targeting policy measures and for evaluating the effects of the measures that are applied. Bioforsk has carried out an evaluation of regional policy measures concerning soil cultivation techniques. The conclusion is that regional adaptation increases the degree to which goals are fulfilled, but that "packages" of several policy measures are also important in particular problem areas.

The lack of significant development trends related to policy measures on this issue may be due to other changes in farming practices. Amongst other things, increased cultivation of winter wheat under Norwegian conditions results in an increased risk of nutrient losses due to run-off. This may also be associated with climate changes, such as increased precipitation and less winter frost. Increased inputs from other sources such as precipitation may also be important.

Targeted and effective environmental interventions require a high degree of knowledge about current state and about the impacts of the different types of intervention. Detailed information is necessary about each individual waterbody and about the management of the surrounding agricultural areas. Gathering reliable data in the field is resource demanding and other means must therefore be found to take account of local variations without having to take large numbers of measurements.

Indicators related to different soil cultivation practices are relevant general indicators, but more specific information is needed to be able to say anything about the conditions in different waterbodies. In priority areas, other measures are often required in addition to changes in soil cultivation practices.

Although indicators do not provide exact information on current state or effects that have been achieved in specific waterbodies, they can provide a basis for comparisons between areas (counties, regions, countries) and information on development trends over time. Indicators therefore also provide a basis for identifying gaps in our knowledge about the relationships between environmental state and the significance of farming practices, climate and soil type. Indicators are therefore important tools for management authorities in the development of policies and policy instruments.

**Stakes and pitfalls of the development of the statistical systems in agriculture: the web of agri-environmental indicators**

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On the basis of various statistical programs in agriculture, in which the author have taken part, this communication address the critical aspects of system integration for public statistical services in the field of agriculture for the building of operational capacities and their relevance for the analysis of public policies, keeping up with their socio-economic environment. In order to illustrate the stakes and pitfalls of the statistical system integration for the building of operational capacities, this paper will study the problems arising from the assessment of the development sustainability in an enlarged
European Union, as regards the agricultural statistics and the new Common Agricultural Policy reform, taking into account the environmental constraints. This paper is based on a review of the sustainable development indicator systems, mainly in their components related to agricultural statistics, and on some conclusions drawn from the French implementation of the corresponding regulations in the light of concepts and knowledge developed in the framework of the 7th European Framework Program for Research and Development. This communication focuses on the analysis of agricultural production practices in order to provide a robust adaptation of the main statistical concepts involved in measuring the environmental sustainability of agriculture in France.

Agri environmental indicators in relation to rural development policy in Flanders, Belgium

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The Flemish countryside is characterised by a good quality of life for all actors in a strongly urbanised environment with a multifunctional use of space. The Flemish rural development policy aims at improving the competitiveness of agriculture and improving the environment and the countryside by supporting land management. The quality of life in rural areas is encouraged by diversification of economic activities. The agricultural sector in Flanders is very intensive with greenhouse horticulture and intensive cattle farming. Different indicators are used for monitoring the rural development policy.

This paper focuses on agri environmental indicators, especially High Nature Value Farming (HNVF) and agri environmental impact indicators.

An analysis of High Nature Value Farming systems in Flanders was conducted. Three different types of High nature farming system indicators were defined and analysed using geographical information.

Impact indicators are very challenging because of site specific circumstances, time lag and difficult cause-effect relations. First an effect indicator for agro environmental investments is presented. Investment policy in agriculture has moved from production enhancing investments towards investments in water reusage, energy production and ammonia emission reduction. For this indicator an administrative database is used.

Secondly effect indicators for evaluating the effect of agro environmental measures are presented. Farmland bird populations have been declining in Flanders for the last 10 years and different agro environmental measures are used for halting this decline.
Nutrient surplus as a tool for evaluating environmental Action Plans in Denmark

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Since the mid eighties, where serious eutrophication and fish death was discovered in costal areas of Denmark, a series of environmental Action Plans have been implemented to reduce the outlet of nutrients from agriculture. One of the tools for evaluating the results of these action plans and to follow the development has been annual estimates of nitrogen (N) and phosphorus (P) surplus from the agricultural sector.

The nutrient surplus is estimated from a farm gate balance using data from Statistics Denmark combined with measured values of N and P contents of individual products. By using the farm gate balance it is not necessary to estimate the internal turnover on the farm between fodder crops and animal manure, which only can be estimated with rather high uncertainty. However, the field surplus can be estimated from the farm surplus by subtracting NH$_3$ losses from stables and storages. The field N surplus can be lost either via NH$_3$ volatilization, denitrification (N$_2$ and N$_2$O) or nitrate leaching or can contribute to the pool of organic N in the soil.

Until now the environmental regulation of the Danish agriculture has been decided by the series of Action Plans and has entirely been based upon legislation, which outlines in detail what is permitted and what prohibited, resulting in today’s very detailed legislation.

The most intensive reduction in the farm gate N surplus took place during the nineties and was primarily a result of

1) the introduction of limits on live-stock units per ha at farm level,
2) statutory rules for utilization of N in animal manure; e.g. 75% of pig slurry is considered to be plant available,
3) N quotas for individual crops setting limits for maximal use of fertilizers.

During the recent years the reduction in N surplus has been less pronounced, which indicates that a limit for the general regulation is approaching. However, to match the goal of the Water Framework Directive a significant reduction is still needed. To reach these goals a new action plan – Green Growth – has been agreed, which will be targeted more to problem areas. In these areas specific measures will be applied, such as constructed wetlands, abandonment of agricultural activity along water courses, increased use of catch crops in specified areas. As something new, some of these measures will be subsidized by the government.
High Nature Value Farming Systems: a Policy Perspective

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Farming practices and the conservation value of farmland are intimately interconnected. Farms, indeed, represent the level at which decisions on land use and management practices are taken.

Economic viability is a necessary condition for farms to work: the abandonment of low-intensity agricultural activities, one of the main threats to HNV farmland, strictly derives from the vulnerable economy of the associated farming systems: technological evolution and market trends favour intensive and specialised productive models, while HNV farms heavily depend on subsidies (Trisorio, Povellato and Bortolozzo, 2008). HVN farmland conservation, in fact, is only attainable through the adoption of sustainable farming practices, beyond ordinary management techniques.

Accordingly, it is fundamental to acknowledge the function of “guardians” of biodiversity to the less intensive and more sustainable farming models: “Conservation of biodiversity in Europe depends on the continuation of low-intensity farming systems across large area of countryside” (G. Beaufoy). This can be obtained through compensations for the higher costs and missed incomes faced by farmers, albeit such economic measures should not be conceived as new mandatory rules imposing heavier burdens, but rather as a compensation for activities already undertaken by farmers.

It is to be noted, moreover, that HNV farming could not only take place in “low-intensity agricultural areas”, but also in areas characterized by intensive agriculture.

Aim of this paper is therefore to investigate the potential use of HNV indicators in the implementation of payment schemes in favour of HNV farms. The expected result is the definition of a set of economic measures tailored on the needs of the different types of HNV agricultural holdings.

References:


EU Agri-Environmental indicators and the Rural Development CMEF indicators (Common Monitoring and Evaluation Framework) a coherent system of analysis

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The importance we attach to assessing the interaction between agriculture and environment is underlined by the fact that the European Commission adopted a list of 28 agri-environmental indicators (AEI) in 2006. The AEI are developed for monitoring the integration of environmental concerns into the Common Agricultural Policy at EU, national and regional levels.

These indicators assess the agricultural production systems, farm management practices, pressures and risks to the environment and the state of the natural resources.
The rural development policy for the programming period 2007-2013 marks a clear distinction from the previous period. In comparison with the past, the current policy takes a more strategic approach and puts a greater emphasis on developing a coherent strategy for rural development across the EU as whole.

In line with this strategic approach to planning and programming, the system of monitoring and evaluation of the rural development policy was redesigned. The requirements for evaluation were reinforced, and a Common Monitoring and Evaluation Framework (CMEF) was developed, in view of guiding Member States towards a more effective system for assessing progress towards community and national objectives, ensuring the accountability of public spending through rural development programmes (RDPs), as well as improving programme performance.

The CMEF consists of a list of common baseline, output, result and impact indicators for the RDPs.

In this context, emphasis is given to the evaluation of the impact of the RDPs on the environment.

The implementation of the CMEF indicators is compulsory for Member states/Regions.

The CMEF indicators include AEI i.e. some data could be used for AEI.

The AEI system covers a wider range of issues, but in a less region-specific manner.

In return, the AEI can be a useful complement to the CMEF in evaluating the RDPs.

The whole system appears a coherent package for analysing progress made in improving the impact of agriculture on the rural ecosystem.

The fate in the environment of biological control agents -
risks and prevention methods

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Since several decades Agro-Environmental Indicators have been developed and used in order to provide to the policy makers and specialised organisations the detailed data base which will provide a realistic indication about the impact of agricultural techniques and practices. Agriculture is an activity which involves a broad scope of practices which all have to be taken in consideration. This is the case of plant protection and the environmental influence of pesticides is one of the major concern and most of the indicators relate to them. However, plant protection alternative and biological measures are being strongly promoted, either in organic farming or integrated pest management (IPM). The paper reviews the characteristics of the different biological control agents and indicate the need to more specifically address to these methods.

Some practical cases describe the fate in the environment of biological control agents , from which the policy makers can better understand and use specific indicators.
In order to assess agricultural policy and performance from the point of view of sustainability, the Swiss Federal Office for Agriculture (FOAG) runs an agro-environmental monitoring (AEM) service based on the relevant Ordinance. The Farm Accountancy Data Network – Agro-Environmental Indicators (AEI FADN) Project gathers and analyses data from individual farms for assessment of the economic situation in combination with individual-farm data on environmental services and their effects on the environment.

As an AEI Competence Centre for the “Driving Forces” and “Potential Environmental Effects” indicator types, the Agroscope Reckenholz-Tänikon Research Station ART is responsible for the AEI FADN Project.

The main objectives of the AEI FADN Project are:

- Extrapolating the individual-farm agro-environmental indicators (AEIs) to the Region and Farm-Type levels;
- Aggregating the data on a national level (where possible), providing the possibility of comparison with indicators calculated on a national level;
- Providing a data pool for combined ecological and economic analyses.

To achieve these objectives, both structural data and production data are collected each year on several hundred farms. In order to minimise the necessary work for the participating farmer, the individual-farm AEIs are as far as possible calculated solely on the basis of data already gathered owing to a previously existing duty to record for the purposes of answering other ecological questions. To this effect, all participating farms are integrated simultaneously into the Swiss Farm Accountancy Data Network (FADN).

The methods for calculating the AEIs on the farm level (in the Nitrogen, Phosphorus, Energy, Climate, Water, Soil and Biodiversity sectors) were developed by research teams from ART, Agroscope Changins-Wädenswil ACW and the Swiss Federal Veterinary Office (FVO). The technical interpretation of the standardised evaluations is performed in partnership with those who developed the methods.

In this way, the AEI FADN Project aims to ensure that the FOAG receives reliable underlying data and methodological bases for AEM and for reporting purposes. In addition, the intention is to lay the foundations so that in future, thanks to further non-standardised analyses, Research will also be one of the beneficiaries of the data collected.
Experiences with the evaluation of agricultural practices for EU Agri-Environmental Indicators

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Several years of research on Agri-environmental Indicators allow to review experiences and outcome about the benefits of AEIs, their usefulness and their value for the development of environmentally friendly agricultural land use. Contributions and studies in the field of environmental impacts of agricultural practices were done in projects like

- Proposals on Agri-Environmental Indicators (PAIS, 2000 – 2005, Eurostat & DG Agri)
- Land Use / Cover Area Frame Statistical Survey (LUCAS, 2001 – 2003, Eurostat),
- Linear Landscape elements as Agri-environmental Indicators (Technical Action Program to Improve Agri-environmental Statistics TAPAS, 2001 – 2002, Germany)
- Biodiversity in Agricultural Landscapes (Technical Action Program to Improve Agri-environmental Statistics TAPAS, 2002 – 2003, Germany)
- IRENA Indicator No 14 Farm management practices (Indicator Reporting on the integration of Environmental concerns into Agricultural policy IRENA, 2004 – 2005, European Environmental Agency)
- Agri-environmental analysis (2006 – 2010, European Environmental Agency)

The AEI Farm management practice covers a wide range of parameters. Limitations are that only few data are available from the field and farm level about cultivation methods and that these are often only given for some countries or regions. Furthermore environmental conditions and farming systems vary within Member states and, consequently, farm management practices vary from one region to another. Therefore it is quite difficult to find standards for management practice to valuate adequate site specific cropping systems.

On the other hand farm management practices have a direct impact on the environment, both on and off the farm. E.g. farmers have to decide whether to till the soil, how to do it and when. With no-till and mulch-till practices runoff can be reduced by about 70%.

This indicator needs to embrace those practices which impact the environment to a high degree and which are underpinned by statistical data sets. Exemplary practices concerning the choice of crops and crop rotations (soil cover) and the introduction of new techniques (tillage systems) were selected for this contribution.

Farm management parameters can provide an early indication of likely changes in the direction of environmental impacts even before they can be measured by other indicators, such as those pertaining to soil and water quality. As well it is more practical and cheaper to measure farming practices than actual changes in the environment. Farm management decisions are strongly influenced by agricultural support measures, environmental regulations, investments in research, education and extension services as well as site-specific environmental conditions. Information on farm management practices,
how these practices affect the environment, and whether they correspond to recommended (or legislated) practices and standards can contribute to support agricultural policies. Resulting from these aspects farm management indicators are obviously closely linked to several indicators as those on nutrient balances soil fertility, soil erosion, water contamination, good farming practices etc.

Above these findings it has to be considered that it is necessary - in spite of all improvements in conceptual approaches and data availability – to always gain an individual and personal view about the agricultural reality. Statistics, algorithms, models and GIS maps must not necessarily reflect the absolute truth. Impressions of farming practices will round off the picture of agriculture in different EU countries.

**French environmental certification scheme: Co-construction of environmental performance indicators**

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**Executive summary**

There is growing interest in the development of schemes to enable farmers and other stakeholders to assess the environmental performance of agricultural holdings. A set of indicators, co-constructed by all stakeholders, could contribute to this objective.

The so called "Grenelle de l'environnement" was convened by the President of the French Republic in 2007. It brought together representatives of five categories of stakeholders: state agents, local authorities, employers, trade unions and non governmental organizations. Its aim was to discuss the major environmental challenges and to address them by proposing collectively shared commitments.

The reflection has been conducted in five workshops most of which were linked to agriculture.

Significantly the sustainable production and consumption workshop mostly discussed agricultural matters, emphasizing the importance of food's production and consumption as a symbol of man's relation with its environment.

A general interest was found for the creation of an environmental certification scheme for agricultural holdings. Such a scheme shall acknowledge current progress towards sustainable practices, create a dynamic to enhance them and create a link between sustainable production and sustainable consumption. As such, this topic is very representative of the whole "Grenelle" process. To succeed, it needs the involvement and the support of all stakeholders: either farmers, agro-industry, public authorities and non governmental organizations.

This scheme is composed of three levels. The first one acknowledges the respect of cross-compliance rules and the accomplishment of a self-assessment of the farm. The second level is based on best practices requirements. At this stage, certification could also be accessed through other existing schemes provided that they have been recognised as having the same level of requirements and control. The third level, "high environmental value", is assessed through environmental performance indicators.

Thus, to respond at the same time to the needs of farmers and of external stakeholders this scheme combines characteristics of an environmental scheme (initial self-assessment, graduation) and of a certification scheme (absolute benchmarking, external certification process). Absolute benchmarking (as opposed to a progress upon an initial diagnosis) appears essential to ensure the adhesion of external stakeholders, particularly NGOs. It is also essential to acknowledge what has already been accomplished.
The third level is the keystone of the whole scheme. Since the earlier stages of reflexion, it the stakeholders chose to be based this level on performance "indicators".

It has been especially difficult to determine these indicators. They should at the same time settle an aim for all farmers and describe a type of agricultural holding all stakeholders agree to qualify of "high environmental value". To settle an aim for all farmers they should be "adapted" to all types of agricultural holdings and take into account the productive dimension. To be recognised by external stakeholders they should take into account all major agricultural impacts on environment and be founded as much as possible on established links to environmental impact, based on scientific evidence.

Reflexion was conducted by a dedicated working group, including representatives of all stakeholders and of technical research institutes. Its proposals were then tested in more than a hundred farms, representatives of the diversity of agricultural holdings, in terms of size, status, productions, former engagement in quality schemes.

This work enabled us to confront indicators to actual pratices. This was all the more important as using indicators in a certification scheme is quite a new topic, most of the schemes being based on practices requirements. Thus stakeholders were in need of concrete examples to "materialize" the link between the indicators and the "reality" they reflect.

The final proposal is composed of two optional set of indicators, designed to cover all types of agricultural holdings and reflecting the values of stakeholders. The first option is a set of compound indicators each of which is dedicated to assess a particular topic: impact on biodiversity, pesticides' strategy, fertilisation's management, water use. The second option relies on two synthetic indicators measuring on one hand self sufficiency, and therefore capacity to use natural ressources as efficiently as possible, on the other hand surfaces dedicated to biodiversity.

**Keywords**

environmental certification, environmental management, agoenvironmental indicators, agricultural practices

**Bibliography**


Eurostat tender on direct and indirect data needs linked to farms for Agri-Environmental Indicators

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This presentation focuses on the need for quality information and cost-effective data collection for the 28 agri-environmental indicators (AEI) identified by the European Commission.

These indicators serve to:

- provide information on the farmed environment;
- track the impact of agriculture on the environment;
- assess the impact of agricultural and environmental policies on environmental management of farms;
- inform agricultural and environmental policy decisions;
- illustrate agri-environmental relationships to the broader public.

However, before agri-environmental data can actually be used by policy-makers, important issues such as representativeness, comparability, and response burden for farmers and others respondents must be tackled. These constraints are linked to the different potential data sources and the need for relevant regional data, with sufficient precision, adequate periodicity, etc.

Thus Eurostat has commissioned a consortium to analyse and summarize the different data requirements, availability and gaps for AEI and other reporting needs, as well as the potential for their combination, harmonisation and optimization. The expected outcome is a set of recommendations for a sustainable system of data collection and reporting. Cooperation with the national statistical institutes and other national authorities (e.g. Ministries of agriculture, of environment) and with international organisations producing and using agri-environmental indicators such as the OECD, is one key element of success for this tender.

Normative, systemic and procedural aspects: a review of indicator-based sustainability assessments in agriculture

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For a long time, sustainability assessment in agriculture has focused mostly on environmental and technical issues, thus neglecting the economic and, above all, the social aspects of sustainability,
the multifunctionality of agriculture and the applicability of the results. In response to these short-
comings, several integrative sustainability assessment methods have been developed for the
agricultural sector. This paper reviews seven of these that represent the diversity of tools developed in
this area.

The reviewed assessment methods can be categorized into three types: (i) top-down farm
assessment methods; (ii) top-down regional assessment methods with some stakeholder participation;
(iii) bottom-up, integrated participatory or transdisciplinary methods with stakeholder participation
throughout the process.

The results readily show the trade-offs encountered when selecting an assessment method. A
clear, standardized, top-down procedure allows for potentially benchmarking and comparing results
across regions and sites. However, this comes at the cost of system specificity. As the top-down
methods often have low stakeholder involvement, the application and implementation of the results
might be difficult. Our analysis suggests that to include the aspects mentioned above in agricultural
sustainability assessment, the bottom-up, integrated participatory or transdisciplinary methods are the
most suitable ones.

Key words: sustainability assessment, indicator, agriculture, sustainability solution space,
 systemic, normative, procedure, implementation.

**Linking Farm-Level Measurement Systems to Environmental Sustainability Outcomes:
Challenges and Ways Forward**

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Agriculture by its very nature has a significant impact on the natural environment. Several converging
trends make it difficult for the world’s farmers to keep up with the growth in food demand from rising
populations and changes in consumption patterns. Based on aggregate global trends and outlooks for
the future, we can conclude that human efforts are not making enough positive difference. Many
unresolved issues require better understanding the links between farm-level practices and outcomes
and impacts at different scales and time frames, including cumulative effects.

Metrics can help in the diagnosis of problems, but also in identifying solutions and driving
 technological changes in a direction that supports these solutions by pricing environmental inputs and
consequences that are currently unpriced. There is increasing urgency to understand what practices
and policies are effective for evidence-based decision-making at all scales, from farmer to policy-
maker. Several trends in science, policy, markets and technology create new possibilities for the
development and use of agri-environmental indicators at multiple scales.

**Metric initiatives** respond to these data demands by developing criteria, indicators, tools and reports to
“measure” sustainable agriculture. The different interpretations of sustainable agriculture result in
multiple conceptual frameworks for organizing and orienting the development of criteria and
indicators. At the heart of the debate over different indicators are not only different views of
sustainable agriculture but different approaches and information needs of users, as well as differences
in how the indicators will be used. This diversity is related to the different lines of accountability,
considering that indicators play a key role in the establishment of accountability to different users or
stakeholders. “Measure what matters” has become a mantra. But measure *what* matters to *whom*, and
*how*? Those interested in using these metrics cannot distinguish one initiative from another, making it
difficult to make choices around which initiative best suits their information needs.
In attempts to capture the complex socioeconomic and environmental relationships in agriculture, many metric initiatives develop lists with hundreds of indicators, which are often process-based and not linked to higher-level outcomes. A proposed solution is a key impact approach, focusing on a few select things that really matter rather than seeking comprehensive coverage, and working with a limited set of indicators and impact proxies linked to models.

There are enormous opportunities to link the data from the hundreds of metric initiatives in existence or in development, operating across scales. Some attempts have been made to coordinate efforts, but the growing diversity of indicator initiatives demonstrates the limited success of harmonization attempts to date and the need for sustained efforts. In this context the focus of the OECD’s coordination of work on agri-environmental indicators represents both a solid foundation and a key opportunity to develop conceptual and methodological consistency in terms of metrics, which may also be essential for more effective policy harmonization.

This paper reviews a number of the issues, constraints and challenges to developing and using indicators at different levels. Assessment is a continuum from farm-level output to higher-scale outcomes and impacts across spatial and temporal scales, with different roles and responsibilities of stakeholders at each level.

We make the following key recommendations for ways forward:

1. Standardize terminology and develop common conceptual frameworks to understand how the different levels, from farms to entire agroecosystems, are related.
2. Coordinate and integrate the various metric initiatives under common frameworks and provide open data platforms to build evidence of what works under what conditions. This knowledge is the foundation for building science-based metrics.
3. Base criteria and indicator development standards on international guides such as the BellagioSTAMP or the ISEAL Codes of Good Practice.
4. Develop capacity.
5. Understand that developing indicators is an evolutionary process, and a perfect, comprehensive set will be elusive—but also unnecessary. The process is a political one, requiring collaboration, consensus and compromise.

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**Indicators in time, space and multiple domains: lessons from applying an integrated assessment tool for agricultural systems**

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In Integrated Assessment and Modelling (IAM) quantitative simulation models are frequently used to compute indicators on several dimensions of sustainability. These quantitative simulation models can be derived from different disciplines and formalisms and can operate on different temporal and spatial scales. In the SEAMLESS project, a set of such models were integrated into an assessment tool for agricultural systems that targets ex-ante assessment of policy and technology changes. Processes at field, farm, regional and EU market level were captured in biophysical and bio-economic models. An example of the integrated use of these models for indicator assessment will be presented.

Based on SEAMLESS several lessons can be drawn with respect to the definition and calculation of indicators. First, the spatial and temporal coverage and integration of existing statistical data sources is crucial to come to a comprehensive assessment and to derive indicators on the different aspects of sustainability. This is not a trivial task as concepts and scales have different meanings in different domains and because of data availability. Second, through typologies and statistical techniques, it is possible to reach a high spatial and temporal resolution of the calculation of indicators. For example, by developing biophysical and farm typologies, diversity in different data sources can be captured and these typologies can be linked through statistical techniques. Hereby many different indicators can be calculated EU-wide for agricultural systems in agri-environmental zones with relatively homogenous conditions for farming. Third, several quantitative models can be used in a standardized and homogenized way to provide consistent indicators across scales if their data requirements and key model outputs have been aligned. Finally, transparency is crucial in relation to the definition, calculation, and delivery of indicators in integrated assessments. On the one hand this requirement is met by developing a software framework that allows the user to explore the calculated indicators. On the other hand we hope to facilitate transparency and to maximise the impact of our efforts by making models and data available under open source conditions.