SENSOR
Sustainability Impact Assessment:
Tools for Environmental, Social and Economic Effects
of Multifunctional Land Use in European Regions

01.12.2004 – 31.05.2009
Start date: 01.12.2004
Duration: 54 months

Project Coordinator:
Leibniz Centre for Agricultural Landscape Research e.V.
Katharina Helming

Report Preparation:
Selected results as of 10 February, 2009

The Integrated Project was prepared under contract from the
European Commission
Contract no 003874 (GOCE) – SENSOR is supported by the Sixth
Framework Programme of the European Union (EU FP6 Integrated
Project), Priority Area 1.1.6.3 "Global Change and Ecosystems"
# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contents</td>
<td>2</td>
</tr>
<tr>
<td>Abbreviations</td>
<td>3</td>
</tr>
<tr>
<td>Introducing SENSOR</td>
<td>6</td>
</tr>
<tr>
<td>The process of impact assessment in the EU</td>
<td>8</td>
</tr>
<tr>
<td>The structural foundation of impact assessment in SENSOR</td>
<td>10</td>
</tr>
<tr>
<td>Spatial Regional Reference Framework</td>
<td>12</td>
</tr>
<tr>
<td>Sustainability Impact Assessment Tools (SIAT)</td>
<td>13</td>
</tr>
<tr>
<td>SIAT model linkages</td>
<td>15</td>
</tr>
<tr>
<td>SIAT mini manual</td>
<td>17</td>
</tr>
<tr>
<td>Indicator framework</td>
<td>18</td>
</tr>
<tr>
<td>SIAT indicators</td>
<td>19</td>
</tr>
<tr>
<td>SIAT fact sheet</td>
<td>21</td>
</tr>
<tr>
<td>Data management system</td>
<td>22</td>
</tr>
<tr>
<td>Baseline 2025 – A counterfactual for policy scenarios</td>
<td>23</td>
</tr>
<tr>
<td>Policy scenarios for impact assessment</td>
<td>24</td>
</tr>
<tr>
<td>SIAT policy scenario: The CAP financial reform – An opportunity for R&amp;D?</td>
<td>25</td>
</tr>
<tr>
<td>Integrated results: Impacts on the sustainability of European regions</td>
<td>26</td>
</tr>
<tr>
<td>Impacts on land use</td>
<td>28</td>
</tr>
<tr>
<td>SENSOR Clippings Environmental, social and economic indicators (a sample)</td>
<td>32</td>
</tr>
<tr>
<td>Monetarised impact valuation: Example, nitrogen surplus</td>
<td>34</td>
</tr>
<tr>
<td>Forest fire risk</td>
<td>36</td>
</tr>
<tr>
<td>Impacts on employment</td>
<td>38</td>
</tr>
<tr>
<td>Impacts on alpine regions</td>
<td>41</td>
</tr>
<tr>
<td>Functions of land use</td>
<td>42</td>
</tr>
<tr>
<td>Regional impacts on Land Use Functions</td>
<td>44</td>
</tr>
<tr>
<td>Participatory impact assessment tools (FoPIA)</td>
<td>47</td>
</tr>
<tr>
<td>FoPIA analytical chain</td>
<td>48</td>
</tr>
<tr>
<td>FoPIA mini manual</td>
<td>50</td>
</tr>
<tr>
<td>FoPIA Policy scenario: Bioenergy – a solution worth promoting?</td>
<td>51</td>
</tr>
<tr>
<td>Silesia: Influence of bioenergy policy scenarios</td>
<td>52</td>
</tr>
<tr>
<td>Stakeholders’ perception of land use functions</td>
<td>54</td>
</tr>
</tbody>
</table>
Malta: The local aspect of sustainability impacts ................................................................. 56
The consequence of being an island ......................................................................................... 59
Latin America: The transfer of the concept ............................................................................. 60
China: The transfer of the model .............................................................................................. 62
Consortium .................................................................................................................................. 66
Impressum ..................................................................................................................................... 69

Abbreviations

B&B Tourism Demand Model
CAP Common Agricultural Policy
CAPRI Common Agricultural Policy Regional Impact Analysis Model
CLUE Conversion of Land Use and its Effects Model
DPSIR Driver, Pressure, State, Impact, Response
EC European Commission
EEA European Environmental Agency
EFISCEN European Forest Information Scenario Model
ESPON European Spatial Planning Observation Network
EUROSTAT Statistical Office of the European Communities
FoPIA Framework for Participatory Impact Assessment
GDP Gross Domestic Product
IA Impact Assessment
IPCC Intergovernmental Panel on Climate Change
IRENA Indicator Reporting on the Integration of Environmental Concerns into Agricultural Policy
LUF Land Use Function
NEMESIS New Econometric Model for Environment and Strategies Implementation for Sustainable Development
NUTS Nomenclature of Territorial Units for Statistics
OECD Organisation for Economic Cooperation and Development
R&D Research and Development
SACS Sensitive Area Case Studies
SEIS Shared Environmental Information System
SIAT Sustainability Impact Assessment Tools
SICK Urban Land Use Model
TIM Transport Infrastructure Model
TTC Targeted Third Countries
WHO World Health Organisation
Research – one of the guiding principles of the renewed strategy for sustainable development – is needed to support the development of monitoring tools such as impact assessment tools and indicators for understanding the evolution towards sustainability. Research also helps to gain better knowledge about the environment, society and economy through policy relevant contributions to the objectives listed in the sustainable development strategy under the seven key challenges (climate change and clean energy, transport, natural resources, consumption and production, public health, social inclusion, demography and migration, global poverty) in order to provide technological and social solutions for clean, resource and energy efficient production and consumption processes. It is only through research that we can find new concepts and paradigmatic shifts out of gridlocked situations, in order to address the decoupling challenge.

Sustainable development itself is, in fact, an object for research where research serves the function of enlightening the complexity of the political, social and economic processes. In my opinion, cross-cutting approaches are very important as long as we recognise that there is no global holistic point of view in the sense of one ultimate integration framework.

Focusing on the integrated level means that there is something else you are not looking at. Integrated results are achieved at the expense of details that may be important in some other circumstance. We should not create the illusion that we can keep in mind everything that matters – and what is out of the dictum is just what does not matter. Research must remain resilient, open and flexible. Disciplines have always been a characteristic of scientific endeavour. New transdisciplinary approaches built on joint research create an organic vision of disciplinary dynamics. It is really my vision of integration to create dense, multiple links and networks across all boundaries. Research should aim for a balance between both, the integrated view on the three dimensions of sustainability and an inside view of the details across these dimensions. This was also one of the challenges for the SENSOR project.
Impact assessment within the European Commission is a political process that prepares evidence for decision-makers on the advantages and disadvantages of possible policy options by assessing their potential impacts. Research plays an important role because policy makers and stakeholders are confronted by two different trends: increasing human intelligence in the economic and political system, and increasing uncertainties about the problems and sustainable solutions. More information does not necessarily imply more certainty on how to act. The same information often resolves in conflicting framings of a problem by different stakeholders and decision-makers. The same is true for the solutions.

Within the SENSOR project, different initiatives are developed to support the practice of impact assessment. Due to the growing interferences between a wide range of global, regional and local developments, the need for new forms of knowledge to underpin policies in general, and land use issues in particular, is increasing. Using scenarios and indicators to assess the impact of policies on different scales, including the European and regional level (NUTS 2/3), SENSOR has contributed to this need. In this project, the scientific expert can be seen not only as a source of knowledge, but also as someone who can facilitate the political dialogue by helping to integrate scientific facts with the different viewpoints of decision-makers and stakeholders.

The importance of land as the very basis of food production is receiving a new appreciation in times of food shortages and in anticipation of climate change. Land is a vulnerable resource that deserves attention in view of preserving our food supply capacity. However, land use is about more than that: land use shapes landscapes and a vast range of visual features, amenities and ecosystems. As desirable outcomes are not necessarily delivered via markets, it is the role of policy to ensure the provision of public goods associated with land use.

Agricultural land use remains a key feature of rural areas, although its relative economic weight is in decline. The ecological integrity and scenic value of landscapes are essential for making rural areas attractive for the establishment of enterprises, for places to live, and for the tourism and recreation businesses. Rural areas provide living space not only for people working there but also for commuters working in urban centres. But again, as many of the valuable land use features are not inherent, they must be provided through targeted policies.
SENSOR Sustainability Impact Assessment

 SENSOR developed quantitative and qualitative tools for ex-ante impact assessment to support decision-making on policies related to land use in European regions. This implies complex interdisciplinary research to obtain results that enable decision-makers to estimate future environmental, social and economic effects of changes in land use in European regions.

Each region in Europe has its unique characteristics and will therefore react to policies and changes in land use in its own way. It is in the interest of policy makers to be able to anticipate these policy responses in order to find the most adequate policy option. Ex-ante impact assessment became important in facilitating policy making for sustainable development. The EU has invested substantial funding to the development of a suite of computer-based models and qualitative tools to substantiate the impact assessment process. One of these initiatives is SENSOR, a four year project, which has brought together teams of researchers from 15 European countries, as well as China, Brazil, Argentina and Uruguay.

In order to make the best use of available resources and avoid unintended side effects, well-informed, robust decisions are needed based on all available data and knowledge put into a regional context. SENSOR’s main product is SIAT (Sustainability Impact Assessment Tool) which is a quantitative multi-modelling tool providing prospective scenario assessment across disciplines, sectors and sustainability dimensions. It is spatially explicit and includes the valuation of simulated environmental, social and economic effects in terms of sustainability impacts. While SIAT is based on quantitative modelling, FoPIA (Framework for Participatory Impact Assessment) is another SENSOR product that complements SIAT with qualitative approaches. The SENSOR partners are confident to present these tools as a valuable contribution to the European Sustainable Development Strategy, the Better Regulation agenda and the ongoing development of impact assessment. Exemplary results of tool prototype applications are presented in this brochure.

In order to provide policy-oriented research results, a comprehensive study of end-user requirements and institutional settings at the EU level preceded the design of SIAT and FoPIA. The major challenge was deriving a trade-off between full flexibility of policy analysis, and robust, quick and easy to use performance.

Interview with Katharina Helming

Scientific Coordination

Katharina Helming
Leibniz Centre for Agricultural Landscape Research (ZALF)

Can you briefly explain the SENSOR project?

SENSOR developed quantitative and qualitative tools for ex-ante impact assessment to support decision-making on policies related to land use in European regions. This implies complex interdisciplinary research to obtain results that enable decision-makers to estimate future environmental, social and economic effects of changes in land use in European regions.

What was the starting point of SENSOR?

Each region in Europe has its unique characteristics and will therefore react to policies and changes in land use in its own way. It is in the interest of policy makers to be able to anticipate these policy responses in order to find the most adequate policy option. Ex-ante impact assessment became important in facilitating policy making for sustainable development. The EU has invested substantial funding to the development of a suite of computer-based models and qualitative tools to substantiate the impact assessment process. One of these initiatives is SENSOR, a four year project, which has brought together teams of researchers from 15 European countries, as well as China, Brazil, Argentina and Uruguay.

What are the main products developed in SENSOR?

In order to make the best use of available resources and avoid unintended side effects, well-informed, robust decisions are needed based on all available data and knowledge put into a regional context. SENSOR’s main product is SIAT (Sustainability Impact Assessment Tool) which is a quantitative multi-modelling tool providing prospective scenario assessment across disciplines, sectors and sustainability dimensions. It is spatially explicit and includes the valuation of simulated environmental, social and economic effects in terms of sustainability impacts. While SIAT is based on quantitative modelling, FoPIA (Framework for Participatory Impact Assessment) is another SENSOR product that complements SIAT with qualitative approaches. The SENSOR partners are confident to present these tools as a valuable contribution to the European Sustainable Development Strategy, the Better Regulation agenda and the ongoing development of impact assessment. Exemplary results of tool prototype applications are presented in this brochure.

In order to provide policy-oriented research results, a comprehensive study of end-user requirements and institutional settings at the EU level preceded the design of SIAT and FoPIA. The major challenge was deriving a trade-off between full flexibility of policy analysis, and robust, quick and easy to use performance.
SENSOR is nearing completion. The usefulness and uptake of SENSOR’s tools and products can only be assessed at a future date. SENSOR explicitly developed a broad view across policy arenas and land use sectors, which allows the user to simulate the impacts of fundamental changes of policy orientation, such as the complete redirection of CAP financial support towards research and development (see example in this brochure). Such drastic scenarios might particularly help decision-makers find solutions in the face of fundamental problems such as the current financial crisis.

Besides the usefulness of the developed products, the scientific advancement is the other criterion to measure the success of SENSOR. Here, the scientific impact is already justified in numerous publications.

The SIAT we have developed in our consortium is a web-based product without specific hardware or user restrictions. With this brochure, the SENSOR consortium would like to inform you about its usefulness and functioning. We also provide information about the experts behind the truly interdisciplinary and integrated tools developed.

The SENSOR approach considers spatially relevant aspects of those land use activities that influence rural sustainability in Europe. The main sectors considered, therefore, are agriculture and forestry, transport and energy infrastructure, and tourism and nature conservation.

Sustainability issues in Europe include demographic changes in rural areas, environmental problems such as post-industrialised regions, the maintenance of ecosystem functioning and landscape character in front of touristic overuse or wood, food and fibre provision, social welfare in less accessible regions such as islands and mountainous regions, and the maintenance of a culturally diverse landscape characteristic of European regions. This variety of sustainability issues, resulting from various land uses and influenced by policies, has been captured by a systematic indicator framework and the Land Use Functions concept which puts the three sustainability pillars into a land use context and allows for a multi-criteria analysis. In my opinion, this is the core asset of the tools we developed: they support the discussion process on sustainable development options by visualising a wide spectrum of scenario impacts.
The process of impact assessment in the EU

Ex-ante impact assessment for European policy-making has two major purposes:
- better regulation
- sustainable development

The first item addresses the effectiveness and efficiency of the intended policy intervention with regard to the policy target (food production, rural development, conservation of natural resources, etc.). A number of tools and methodologies are available to analyse these questions, predominantly based on the Standard Cost Model and Cost Benefit Analysis.

The second purpose of sustainable development is more difficult to capture. It deals with externalities and addresses the occurrence of unintended side effects regarding social, economic and environmental variables in the system. These effects might influence sustainable development of specific regions, societal groups or sectors.

With this second aspect of impact assessment, a link is made between the objective of better regulation and the European Commission’s commitment to sustainable development.

Impact assessment is carried out in six steps (adapted from the EC Impact Assessment guidelines, CEC 2005).

In stages 4 and 5, quantitative impact assessment tools are most likely to be applied. This is also where the SENSOR products apply. Between stage 3 and 4, a feedback loop is possible when policy-makers decide to refine the options. Stakeholders may be involved throughout the process.
The maintenance of ecosystem processes such as filtering and buffering of energy and weather is highly variable on a small scale and very difficult to predict. General large-scale trends, however, will not be considerably affected by changes in the financial regime of CAP.
The structural foundation of impact assessment in SENSOR

Impact assessment in SENSOR employs scenario techniques to allow for anticipations of the future sustainability of policy induced land use changes in European regions. The architecture of the Sustainability Impact Assessment Tools developed in SENSOR is based on:

- linking socio-economic trend scenarios and policy options with land use changes via coupled model simulations;
- linking land use changes with environmental, social and economic impacts via indicator analyses and;
- valuating these impacts in light of sustainable development targets by applying an expert- and stakeholder-based valuation framework.

The architecture is based on the EEA’s Driver-Pressure-State-Impact-Response framework. The framework was implemented within SENSOR both in a quantitative modelling approach (SIAT) and a fully qualitative participatory approach (FoPIA). It was applied as follows: The end-user generates policy scenarios. New economic, fiscal, or legislative conditions arise from these scenarios which, combined with global socio-economic trend scenarios, act as drivers of landuse change. The pressures are the predicted changes in land use types and management by the year 2025. States are reflected by changes in social, environmental and economic systems as evidenced by a total of 86 indicators for NUTS2/3 regions across Europe. Sustainability impacts are assessed by comparing indicator value changes against sustainability thresholds and targets, thereby integrating expert knowledge and stakeholder deliberations into one valuation system. Regional impacts on ‘Land Use Functions’ are calculated and compared to regional limits. The responses, or the decisions made in light of the assessment results, are the prerogative of the end-user.

Analytical approach of the sustainability impact assessment tools developed in SENSOR

Helming 2008
To be policy relevant, the approach simultaneously considers the spatially relevant aspects of those economic sectors and activities that are involved in rural land use at the European level. These include agriculture and forestry as main sectors, and transport infrastructure, energy, nature conservation, tourism and urbanisation as peripheral conditions. While seemingly simple, this approach requires complex interdisciplinary cooperation.

SENSOR puts emphasis on regional sustainability. While on the one hand scenarios combine global socio-economic trends with European policies, specific (environmental) processes are on the other hand analysed at fine (1km²) grid. Policy impacts are assessed at the regional level (NUTS 2/3) thereby taking into account regional particularities. SENSOR developed the Spatial Regional Reference Framework which combines NUTS 2 and NUTS 3 regional boundaries and clusters European regions on the basis of socio-economic and geophysical parameters.

The main feature of the SENSOR tool is keeping the three dimensions of sustainability equally weighted.
Spatial Regional Reference Framework

One of the prominent objectives was to examine whether, where and to which degree the expected European trends and changes were going to impact regional sustainability issues.

The approach builds upon the following assumptions:
1. Regional characteristics determine the scale and scope of impacts upon sustainability resulting from land use changes
2. Independent of administrative boundaries, environmental and socio-economic profiles define regional coherence and differences across the entire EU territory
3. Taking regional characteristics into account will facilitate expert and stakeholder participation in impact assessment
4. Understanding and addressing these regional characteristics will greatly improve the interpretation of the impacts with regard to their likely environmental, social and economic effects

Most of the SENSOR results are displayed for Europe at the NUTS x level, which is a combination of NUTS 2 and NUTS 3 units to derive relatively homogeneous regions. All data are based on the EEA reference grid and INSPIRE standards. In addition to the NUTS x level, a cluster analysis was performed to find an operational way for aggregating the approximately 570 NUTS x regions to 30 regions. This relatively low number of clusters was deemed necessary for facilitating the expert assessment of thresholds based on regional characteristics. Clustering was performed by integrating biophysical, socio-economic and regional administrative aspects of the European territory. The statistical procedure of clustering provides transparency and allows the inclusion of additional variables if necessary.
Decision support tools are required at the European level to provide scientifically substantiated anticipations of the effects of future policy options on sustainability issues. Models can provide important content in the impact assessment process. SENSOR responded to the information needs at European land use policy level with the development of SIAT (Sustainability Impact Assessment Tool), which allows the assessment of land use policy effects on sustainable development at a scale for Europe.

A key element of SIAT is that it applies a cross-sector approach to land use at national and regional levels. The interactions are captured using a combination of sector and macro-economic models. The set-up incorporates a broad range of more than 80 indicators in an interdisciplinary way. The cooperation with a cluster of specialised institutes from various disciplines ensures precise research work.

The usability of the tool is illustrated by the policy cases we implemented, but for regular application we certainly need the end-user's support to maintain it by up-dating data bases and adjusting it to more policy cases. However, apart from the actual tool, I would say that during the development process, scientists as well as end-users went through an intensive learning process. A new research network has been established. The knowledge gained is very much up to date.

The adaptation to new policy cases requires the integration of new response protocols into the system. Modifying the implemented policy cases needs some time and requires SENSOR experts and the use of the modelling framework. The level of integration, however, has made an analysis of trade-offs among six sectors possible: agriculture, forestry, nature conservation, transport infrastructure, energy and tourism. The analytical broadness of the model enables the understanding of complex issues with limited pre-knowledge and easy operability.

Transparency is one of the modeller’s crucial tasks. This involves deciding which information should be displayed as explicit knowledge and to what extent implicit knowledge suffices. If the system is not clearly understood, the tool may be immediately discarded. In SIAT, transparency is ensured, for example, by fact sheets that explain each step, but we also need to explain our calculations in detail and demonstrate how the results can be traced back.
The reduction of the pillar I CAP budget might lead to a decrease in the provision of work in agriculture. Scenario results show that, overall employment might increase due to the effect on GDP growth, particularly when savings are redirected to research and development. Still, employment challenges will remain in rural areas.
In SENSOR, the impact of policy scenarios is measured by indicators. In between the policy scenarios and the indicator computations are models. The models involved are complex and require long computation time, whereas the end-user of the impact assessment tool SIAT wants prompt results. The strategy followed in SENSOR is capturing the reactions of key model results, required for indicator computations, to changes in a selected set of policies by response functions. In SIAT, the outcomes of the response functions are used instead of the true models as inputs in the indicator computations. The response functions are econometrically estimated based on the results of a large number of simulation experiments with the full-model system. Understanding the outcomes of SIAT requires some insight into how the underlying system of models works. This is illustrated in the following figure.

In the figure above, square items represent data, whereas rectangular boxes represent some form of computation. The arrows represent a flow of information. The models work in a branched chain. First NEMESIS, a macroeconomic model, solves for partial equilibrium over all sectors that are studied. This includes making use of sub-modules for tourism (B&B), transportation (TIM) and urban land use (SICK). The total land area is split between unusable land, nature, transportation infrastructure, urban land, forest and agriculture.

The starting point of the information flow is the set of policy variables available in SIAT (square number 1). The policy variables are the “knobs the user can turn” in order to investigate the impact of a range of policy changes. The end point of the flow, and of interest to the policy-maker, is the set of impact indicators (square number 3). The indicator results are computed by indicator functions, which are based on policy settings, other data (not shown) and model results (square 2). When the policy-maker or researcher is using SIAT, the model results are
computed using response functions. The response functions have been generated in the
developing phase of the project carrying out simulation experiments with the system of
models shown in the large box on the left side of the figure.

With particular attention to land use changes, this is how the model linkages work: In practice,
each simulation experiment starts with CAPRI, an agricultural sector model. CAPRI uses
information from the other models, in particular, utilisable agricultural area $A_a$ together with
current policy to compute agricultural production, output prices and especially land prices $\lambda$. NEMESIS uses the information from CAPRI, i.e., land prices, total output of agriculture, and
agricultural price index to update its land demand function for agriculture. In other words,
NEMESIS uses the information from CAPRI to obtain a better estimate of how land prices in
agriculture respond to changes in available land. NEMESIS also takes the total agricultural
output quantities and prices from CAPRI as given, and then solves for a new equilibrium
solution using all land balances. Each member state contains one land balance, which
requires the total land area to be shared among agriculture, forestry, urban land use, transport
infrastructure, protected areas (fixed) and land unsuitable for exploitation (fixed). The land
use shares depend on the economic equilibrium of all sectors, and thus, particularly on the
feedback obtained from CAPRI. DYNA-CLUE, a land use model, disaggregates the land use
shares coming from NEMESIS into a square kilometre grid and into regional levels required by
CAPRI and EFISCEN. EFISCEN computes forestry-related results based on management policy,
available area and demand for wood. That completes one iteration. After each iteration, key
model results are evaluated to check for convergence, and if convergence has not been
obtained, the solution process starts again with CAPRI.

A key advantage of using a system of linked models is that it makes the simultaneous
consideration of all sectors of the economy (within NEMESIS) possible without abstaining from
a great level of detail for sectors of particular interest, i.e., agriculture and forestry. No model
used by itself could obtain the rich set of results produced within SENSOR. Furthermore, by
evaluating the results of simulation experiments with the whole system versus results obtained
from the same models without linkages, a measure may be obtained to the extent of which
the linkages matter significantly to the outcomes. The results of such a comparison are clear.
Indeed, a policy shock introduced in one sector (for example, agriculture) also significantly
affects other sectors, and the effects on the sector where the shock was introduced also
clearly depend on the interaction with other sectors.

“Of course it must be understood that it is a model. We ask a question to a model and the
model plays back another question. This is a question we did not think of before, but it is
extremely helpful in the discussion process. And this, in effect, draws us closer to the answer
of the original question.” (Paul Zagamé, ECP)

Torbjörn Jansson (LEI)
The Sustainability Impact Assessment Tool (SIAT) is one central output of research conducted within the SENSOR project: a ready-to-use application that results from four years of integrated research. SIAT allows the user to conduct integrated analyses across the sectors agriculture, forestry, energy, transport infrastructure, nature conservation and tourism. Simulations for ex-ante impact assessment can be carried out for the target year 2025 covering 574 European regions of the EU 27. Each simulation computes 87 impact indicators and nine Land Use Functions (LUFs) that illustrate the policy impact on social, economic and environmental goods and services at a national as well as regional level.

**Step 1**  
**Main menu**  
Select application or information
The first step allows the user to enter the Impact Assessment Application. An optional feature offers a complete set of fact sheets containing all SENSOR background information. The two features are linked so that the user can call up background information at any time and for each step of the calculation. These shortcuts help maintain the transparency of the tool.

**Step 2**  
**Impact assessment**  
Choose a policy case and settings
The SIAT user identifies a policy case, i.e., the thematic area that is to be simulated. For each policy case, a set of policy instruments can be combined in various ways and different intensities (in a pre-defined range), e.g., the agricultural support subsidies in millions of Euro. Each step of the analysis can be saved to the hard drive in order to compare settings. As soon as all settings have been entered, the model chain calculates simulations that will be interpolated and displayed.

**Step 3**  
**Results**  
Selection of graphical means on land use
The chosen policy option, which is the specific settings of the current calculation, will be assessed at the level of single indicators or summarised and synthesised through a multi-criteria analysis into sustainability impacts shown by the change in Land Use Functions. When different policy options are compared, trade-offs become apparent. Sustainability criteria such as critical limits provide the means to valuate the policy impacts. All results can be displayed and downloaded as maps, tables or bar charts. Spider diagrams allow an easy comparison of simulations with different settings.
Indicator framework

The selection of the set of indicators was a long process. We tried to direct this process by creating a framework to ensure end-user orientation. To a large extent, the SENSOR project is a modelling exercise which can easily remain supply driven, but we wanted to make it as demand driven as possible. By determining specific criteria for indicator selection, we ensured a harmonised approach across the SENSOR project and also provided the balancing of the indicator sets to cover all three dimensions of sustainable development.

In general, SENSOR indicators should be selected from already existing and well-tested indicators. During the selection process, all SENSOR researchers could state their opinions as to which indicators would both suit the framework and also depart from the SENSOR criteria for indicator selection.

There is a set of basic criteria for indicators, in that they have to be conceptually and methodologically sound. We made an extensive review of existing European indicator sets. Today 50-100 relevant indicator sets and frameworks exist for describing different aspects of sustainable development in relation to landscape at the European and national level (e.g., EU IRENA, EEA, OECD, EUROSTAT, United Nations, WHO). In SENSOR, a specific set of criteria was needed to respond to the specific land use sectors that were looked at: agriculture, forestry, nature conservation, transport infrastructure, energy and tourism. In the context of SENSOR, this implies that indicators should try to answer the question: "What are the impacts of a policy option?"

The indicators were chosen for their sensitivity towards the spatial level of the SENSOR work, which is the NUTS x level and the time frame: 2025. Most important was the policy relevance criterion. These criteria should be ensured by the framework which was closely related to the EU impact assessment guidelines.

An indicator should be applicable in a sufficiently comparable way across Member States, and comply with the standards applied by EU systems (Eurostat and EEA) and other international organisations, such as the UN and the OECD. SENSOR indicators should generally be selected from already existing and well-tested indicators. Incidentally, information about the indicators used can be accessed from SIAT. The application is linked to fact sheets that provide background information on the indicators.

Interview with Pia Frederikson
Integrated Data and Indicator Management

Pia Frederikson
National Environmental Research Institute, Aarhus University (NERI)

How did you come to the specific set of indicators used in SENSOR?

The selection of the set of indicators was a long process. We tried to direct this process by creating a framework to ensure end-user orientation. To a large extent, the SENSOR project is a modelling exercise which can easily remain supply driven, but we wanted to make it as demand driven as possible. By determining specific criteria for indicator selection, we ensured a harmonised approach across the SENSOR project and also provided the balancing of the indicator sets to cover all three dimensions of sustainable development.

In general, SENSOR indicators should be selected from already existing and well-tested indicators. During the selection process, all SENSOR researchers could state their opinions as to which indicators would both suit the framework and also depart from the SENSOR criteria for indicator selection.

What were the SENSOR criteria for the indicator selection?

There is a set of basic criteria for indicators, in that they have to be conceptually and methodologically sound. We made an extensive review of existing European indicator sets. Today 50-100 relevant indicator sets and frameworks exist for describing different aspects of sustainable development in relation to landscape at the European and national level (e.g., EU IRENA, EEA, OECD, EUROSTAT, United Nations, WHO). In SENSOR, a specific set of criteria was needed to respond to the specific land use sectors that were looked at: agriculture, forestry, nature conservation, transport infrastructure, energy and tourism. In the context of SENSOR, this implies that indicators should try to answer the question: "What are the impacts of a policy option?"

How did you ensure data availability and usability of the criteria?

The indicators were chosen for their sensitivity towards the spatial level of the SENSOR work, which is the NUTS x level and the time frame: 2025. Most important was the policy relevance criterion. These criteria should be ensured by the framework which was closely related to the EU impact assessment guidelines.

An indicator should be applicable in a sufficiently comparable way across Member States, and comply with the standards applied by EU systems (Eurostat and EEA) and other international organisations, such as the UN and the OECD. SENSOR indicators should generally be selected from already existing and well-tested indicators. Incidentally, information about the indicators used can be accessed from SIAT. The application is linked to fact sheets that provide background information on the indicators.
The impact issues are based on the Impact Assessments Guidelines published by the European Commission. The indicators were selected to link land use changes to these issues.

<table>
<thead>
<tr>
<th>Impact Issue (CEC 2005)</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENV 01 Air quality</td>
<td>Ammonia emission from agriculture, Nitrogen oxide (NOx) emissions</td>
</tr>
<tr>
<td>ENV 02 Water quality and resources</td>
<td>Nitrogen (N) surplus, phosphorus (P) surplus, water retention capacity of the soil</td>
</tr>
<tr>
<td>ENV 03 Soil quality and resources</td>
<td>Soil erosion risk by water, soil sealing, wind erosion, soil carbon content</td>
</tr>
<tr>
<td>ENV 04 The climate</td>
<td>CO2 emission, methane emission, nitrous oxide emission, carbon sequestration in biomass, soil and dead organic matter</td>
</tr>
<tr>
<td>ENV 05 Renewable or non-renewable resources</td>
<td>Fossil energy demand area, fossil energy demand animal, biomass potential</td>
</tr>
<tr>
<td>ENV 06 Biodiversity, flora, fauna and landscapes</td>
<td>Terrestrial habitats at risk from eutrophication, population trends of farmland birds, deadwood, spatial cohesion, pesticide use</td>
</tr>
<tr>
<td>ENV 07 Land use</td>
<td>Land use change (in 9 classes)</td>
</tr>
<tr>
<td>ENV 08 Waste production/generation/recycling</td>
<td>Generation of municipal waste by tourists, discharge of sewage water due to tourism</td>
</tr>
<tr>
<td>ENV 09 The likelihood or scale of environmental risk</td>
<td>Forest fire risk, global warming potential</td>
</tr>
<tr>
<td>ECO 01 Competitiveness, trade and investment flows</td>
<td>Net flows of traded goods in agriculture, forestry and the energy sector</td>
</tr>
<tr>
<td>ECO 03 Operating costs and conduct of business</td>
<td>Labour cost per sector, energy cost</td>
</tr>
<tr>
<td>ECO 04 Administrative costs on business</td>
<td>Administrative costs</td>
</tr>
<tr>
<td>ECO 06 Innovation and research</td>
<td>Labour productivity</td>
</tr>
<tr>
<td>ECO 07 Consumers and households</td>
<td>Inflation rate - consumer price index</td>
</tr>
<tr>
<td>ECO 08 Specific regions or sectors</td>
<td>Gross value added per sector (agriculture, forestry, tourism, energy)</td>
</tr>
<tr>
<td>ECO 10 Public authorities</td>
<td>Public expenditure</td>
</tr>
<tr>
<td>ECO 11 The macroeconomic environment</td>
<td>Gross domestic product</td>
</tr>
<tr>
<td>SOC 01 Employment and labour markets</td>
<td>Unemployment rate, employment by sector (both sectoral and total)</td>
</tr>
<tr>
<td>SOC 03 Social inclusion and protection of particular groups</td>
<td>Deviation of regional unemployment, deviation of regional income</td>
</tr>
<tr>
<td>SOC 07 Public health and safety</td>
<td>Exposure to air and water pollution, exposure to fire risk</td>
</tr>
<tr>
<td>SOC 08 Crime, terrorism and security</td>
<td>Self-sufficiency index for food (calories, fat, protein)</td>
</tr>
<tr>
<td>SOC 09 Access to and effects on social protection, health and educational system</td>
<td>Migration</td>
</tr>
<tr>
<td>SOC 10 Tourism pressure</td>
<td>Social tourism pressure, recreational pressure from tourism</td>
</tr>
<tr>
<td>SOC 11 Landscape identity</td>
<td>Continuity of appreciated landscape heritage, change of visual attractivity</td>
</tr>
</tbody>
</table>

Residential area and land independent production is not directly affected by any changes in land use policy scenarios on a European scale. However, scenarios forecast considerable increase in GDP when financial support for agriculture is reduced and shifted to research and development. This implies an increase in industry and services.
Deadwood is all non-living woody material not classified as litter. It includes standing dead wood, dead wood lying on the surface, and stumps. The indicator is expressed in tons of dead mass per hectare (ton ha⁻¹).

The indicator is responsive to changes in forest management regimes and intensity, and thereby to SENSOR policy scenarios. It is a state indicator, which is a proxy indicator for impacts on the naturalness of forests in Europe.

Besides its dependence on management, the amount of dead wood is determined by productivity, decomposition rate, pattern of natural disturbances, succession stage, forest history and human intervention.

Projections for deadwood stocks in 2025 are available from the forestry sector model EFISCEN. This model has been extended with a new module for this purpose.

A module in EFISCEN models natural mortality and dead-wood dynamics to assess the impact of policies on the amount of dead wood in forests.

**Long version pdf**


Project deliverable report


Project deliverable report
A huge amount of data related to landuse already exists. SENSOR builds upon these data sets, because they are already accepted for policy-making support. Furthermore, several data sets are produced within SENSOR. However, to provide useful information in a project like SENSOR, we obviously needed a framework specifying which issues should be covered by the impact assessment tool developed, and which data we needed for that. Data available from EUROSTAT, ESPON and other sources are available at the NUTS 0 – NUTS 3 levels. Therefore, we also needed tools to aggregate and disaggregate between various NUTS levels and NUTS x.

Because data quality is a very important issue in all database development projects, a major aim has been to identify and describe various methods and tools to enhance and document the quality of data produced by the SENSOR project. SENSOR developed a metadata profile and a web-based metadata reporting system, as well as methods for cross-referencing and consistency checking.

The data management system is based on recent international standards, and the system is compliant with the implementing rules of the INSPIRE Committee as well as the concept for Shared Environmental Information Systems (SEIS). According to these principles, the data management system was developed using open standards as well as industry standards facilitating easy discovery and access to data. The Digital Policy Information System was integrated into the data management system, thus facilitating the search for policy information together with GIS data and other tabular information.

The policy documents are linked to NUTS regions. SENSOR’s data management system is the main provider of NUTS-based tabular data for the SIAT system. SIAT calculations are carried out using continuously maintained data through online access to the data management system.
SENSOR developed forecasting simulation tools in which future policy options can be analysed for possible sustainability impacts. Scenarios show the assumed future state of affairs – the conditions that would be expected to develop in the absence of any change in policy intervention (baseline scenario), and the spectrum of possible future situations where the policy is implemented (policy scenarios). Thus, the impact of any changes in particular policies can be compared. The projection year 2025 meets the decision-maker’s requirements for medium-term perspectives.

Five driving forces have been chosen to describe the socio-economic situations:
- demographic change within Europe
- the rate of participation in the labour force
- growth of world demand (outside Europe)
- the price of petroleum on the world market
- expenditure on research and development

The baseline scenario was calculated by extrapolation of existing data and adjusted, when available, using expert judgement on expected changes in trends. The data were taken from Eurostat, UN, IPCC and OECD. The projected changes are shown below. They show long-term trends and do not contain short-term oscillations.

European population growth of 0.4% in 2005 will decrease to almost 0% in 2025. Compared to 2005, the total population difference will be much smaller than the changes in the demographic structure of the population. Similarly, the total labour force as a percentage of the population in 2025 will be virtually the same as it is today (47.7%, 2005): 48.1% compared to 47.7% in 2005. Calculations predict a decrease in world annual GDP growth from around 4% in 2005 to 2.7% in 2025, while the oil price is expected to remain constant until 2025 irrespective of short-term oscillations. Expenditure for research and development is expected to continue today’s trend of 2.5% increase per year.

The SENSOR modelling chain was employed to translate these driving forces into pressures of land use changes. Policy scenarios will be analysed in comparison to this baseline scenario.
Policy scenarios for impact assessment

Interview with Tom Kuhlman
European Land Use Scenario Assessment and Forecasting

What is a policy case in SENSOR?

A policy case is a thought experiment as to what would happen if a certain policy case was implemented. It contains a set of policy scenarios whose relationship with various aspects of sustainability has been determined by modelling. The aim of the SIAT model is to enable policy-makers to design their own policy scenarios and immediately assess the impact on sustainability. Together with stakeholders and experts, we selected the financial reform of the CAP, bioenergy, biodiversity, forest and transport as example cases to construct SIAT. All cases are relevant to multifunctional land use in that they cover all six sectors of land use: agriculture, forestry, nature conservation, transport infrastructure, energy and tourism.

Was the choice of policy cases correct?

Already in 2006 we estimated that the policy cases would still be relevant in 2009. At that time we were most interested in the bioenergy policy case, not quite knowing how important the issue would become, when the biofuel directive was resolved. The political relevance of biofuels changed a lot in just two years. Current discussions concern the environmental effects of biofuels. This shows that the debate itself is very relevant and that SENSOR can contribute to it.

What if a policy-maker would like to know results for a new policy case?

Ideally, one would wish to have a SIAT in which the end-user can design any policy scenario and assess its impact. In practice, however, SIAT can assess a policy scenario only if it contains response functions for the particular instruments that are to be applied in the policy. Flexibility exists in the settings chosen for a particular scenario, i.e., how much subsidy or taxation is to be applied, or what quantity of greenhouse gas emissions will be tolerated. SIAT response functions offer the flexibility to specify scenarios.

What happens if the drivers change? Does that make your calculations invalid?

If there is a change in the baseline driver, it would of course change the outcomes for GDP or agricultural land use. However, that was not really what was expected from the SENSOR research. What we can show, for example, is whether an increase of bioenergy subsidies would lead to more or to less agricultural land use. This conclusion we certainly hope is valid.
SIAT policy scenario: The CAP financial reform
- An opportunity for R&D?

In December 2005, a new long-term EU budget was agreed upon for 2007-2013. A thorough financial reform will be decided upon before the next financial perspective in 2012.

The largest item on the EU budget is the Common Agricultural Policy (CAP). Agriculture and forestry are the main land use types and therefore play a key role in the management of natural resources. This is especially true for rural areas that make up 90% of the EU and the living area for 50% of the EU population. The CAP is certainly one key policy influencing the sustainability of developments in rural European areas, for instance, by shifting priorities from production support to fostering a sustainable use of natural resources in rural areas. It was decided on in 2003/2004, and its impacts were evaluated with the Health Check. The analysis of the consequences of the reforms illustrates the need for an assessment of impacts and trade-offs of future policy options. Questions include: What, in general, are the possible consequences on biodiversity and the environment stemming from the proposed ending of compulsory setting aside of land? What could be the societal effects of direct payment changes? Which policy option can effectively promote competitive multifunctional agriculture?

Undoubtedly, the CAP revision will be a major point of discussion of the financial reform in 2013. The two most fundamental options for future agricultural policies are:
- continuing income support to farmers, or
- cutting expenditures

Should the latter be considered more favourable for the EU, the impact on farmers, natural resources and rural regions would have to be assessed responsibly. The same is true for all options of alternative spending. The savings could, for example, be returned to the taxpayer or, according to the Gothenburg and Lisbon strategies, be returned indirectly by investing in research and development. Since the Lisbon strategy aims to increase the 1.84% expenditure of GDP for research and development in the EU to reach a strong economic performance and sustainable use of natural resources, the latter seems to be very much in tune. But can we be sure that such a policy really has the intended impacts?

It is for that reason that the SENSOR consortium decided to make the effects of a financial reform towards an increased spending for R&D evident for policy-makers. SENSOR research presents some answers to the question: “What would happen if saved financial means from the Common Agriculture Policy in pillar I (direct payments and market support) were reduced and re-spent in research and development?”

<table>
<thead>
<tr>
<th>Exogenous trends in world market &amp; population</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline:</strong> no policy change</td>
</tr>
<tr>
<td><strong>CAP reform:</strong> budget 1st pillar</td>
</tr>
<tr>
<td>0 % 100 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SENSOR CAP financial reform scenario options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return savings via tax rebate</td>
</tr>
<tr>
<td>Invest savings in research and development</td>
</tr>
</tbody>
</table>
For a long time, the financial support provided by the Common Agricultural Policy (CAP) has been the biggest expenditure within the EU budget and to date is undoubtedly an important means of rural income. At the same time, policy-makers must continuously assess its impacts on the sustainability of rural areas in relation to the overall EU strategy. In order to backup discussions on effects of the CAP, the SENSOR consortium has calculated a contrasting scenario of cutting 100% of the first pillar measures (direct farming support and market support). The questions concern the effect on sustainable development of European regions if savings were returned to the tax payer or, in a second scenario, if savings were redirected to support research and development.

A first overview shows that complete abolishment of CAP financial support (pillar I) generally leads to a fall in agricultural prices and food prices, but also to an overall increase in GDP and household consumption. The comparison of alternative budget spending shows that R&D re-investment can achieve more lasting and widespread beneficial effects over sectors and social groups than tax rebate.

It can already be stated that independent of SENSOR calculations, farming is starting to become less important as a source of employment in rural areas yet it still plays a vital role in preserving rural landscapes and providing natural resource functions. The falling number of employees in agriculture had been impeded by the CAP since 1992. A reduction of pillar I measures would potentially accelerate this development and structural change in agriculture. It reduces agricultural income by 30% to 40%, followed by a decrease in agricultural employment by about 25%. Not surprising, since the CAP is aimed at stimulating agricultural production, its discontinuation will lead to a price reduction followed by a decrease in value added. Agricultural area will decrease up to 2.5%. It depends on each country if this is significant or not. Forest area is expected to increase by 0% to 4%. Agricultural land per farm is expected to increase, thus compensating income losses.
Countries which for historical reasons, do not depend so much on market support or specialise in less subsidised intensive agriculture experience little decline. In general, it can be said that the more a country benefited from the CAP, the more sensitive it is to reform in terms of production loss. This is significant especially for Spain and some of the Eastern EU countries. However, in considering the total of all European agricultural production, no harmful impact is expected. Productivity will even increase or change tremendously at the regional level. The only sensitive production sector is beef production. In countries such as Finland, where the agricultural sector is very small, it is feared that agriculture would be completely abandoned without incentives. Hungary, Portugal, Romania and Poland will be susceptible to higher unemployment rates.

In contrast to agricultural incomes, overall incomes would increase after the reform. At the same time, agricultural employment would suffer while overall employment would increase. Via the indicator sets, SIAT has the capability to assess the effects of expected changes on target groups based on their current sectoral employment status. For example, women are likely to benefit, albeit marginally, from shifts in employment in countries such as Greece, Ireland and the Baltic states. In other countries, however, the employment rate would decrease compared to the baseline, notably in Italy and Austria. This may be due to a relatively high proportion of women in agricultural jobs compared to men.

The projections show an overall improvement regarding the decrease of phosphorus surplus, ammonia emission, wind erosion or habitat eutrophication, but a problematic increase of pesticide use, methane emission and forest fire risk. Indicators such as standing deadwood and nitrogen surplus do not show a consistent effect. Some regions do improve, others worsen. There is often a strong regional dimension to the pattern of change. This is illustrated by phosphorus surplus where Eastern European countries such as Romania and Bulgaria improve, while in parts of France, Spain and Scandinavia, phosphorus surplus increases dramatically. The small-scale variation can be considerable. This can be illustrated by standing deadwood where adjacent NUTSx regions show increases and decreases. Results from other policy settings suggest that indicator responses are not always linear. In other words, complete removal of direct farm support may have less impact than partial removal of direct farm support.

The regional differences seem to be indicator-specific, suggesting that an analysis of trade-offs must be addressed at the regional level. This is a powerful justification for an assessment that takes regional specifications into account. A comparison of the patterns of change with the actual values in the reference scenario shows that the areas showing most changes are not necessarily the ones that need huge improvements regarding sustainability. SIAT provides the policy-maker with the necessary tools to evaluate these complex results at EU and regional levels.
Impacts on land use

The SIAT simulation of the policy case concerning the financial reform of the EU budget examines changes in financial support for the agricultural sector. Calculations were based on a cut to 0% subsidising of agricultural markets and no direct farm income support, and instead reallocating saved subsidies to an increased funding for research and development. Results from running NEMESIS demonstrate that decreases of agricultural land are a common output at the national level. In most cases, the total area of arable land decreases more than the total area of grassland. By comparing the two maps, two processes become apparent. For instance, areas in northern Germany and the UK with a strong decrease in arable land correspond with areas showing an increase in grassland area. This means replacement of arable land by grassland is followed by an increased abandonment of grassland in marginal areas.

These spatial shifts in grassland areas can be attributed to the location characteristics of arable land. For the most part, arable land corresponds with good agricultural soils. Upon decrease of the arable area, this land remains suitable for agricultural use and is therefore converted to grassland. Increased grassland production at these locations, however, triggers abandonment of mostly extensively managed grassland areas on hill slopes and mountainous areas which have rather unfavorable conditions for agricultural practices.

The first locations to be abandoned are marginal areas either poorly accessible or with soil and climate constraints. In general, these are heterogeneous landscapes with a mosaic of grassland, arable land and patches of natural vegetation with a high value for agrobiodiversity and cultural heritage. Land abandonment in these regions results in regrowth of natural vegetation, leading to a more homogeneous landscape dominated by larger continuous areas of forest. As a consequence, this may provide benefit in terms of viable living areas for large mammals and other species.

The land cover pattern of large-scale agricultural areas in the most important agricultural regions are less sensitive to changes in the Common Agricultural Policy. They will remain predominantly agricultural areas. This does not mean that other aspects of farming (e.g., farm income) are not affected. The changes would, however, be felt mainly in the marginal regions. This would also be true for a case of expansion of agricultural area. Conversions of arable land to pasture land are mainly found on the edge of the main arable cropping regions and in landscapes showing a complex pattern of intermixed grassland and croplands.

Urbanisation patterns, in contrast, would not be affected by this policy case. Land cover patterns would remain the same, resulting in an overall loss of the most productive farmlands.
CAP financial reform scenario: 100% cut of first pillar measures; re-investment of savings in research and development.

Impact on the area covered by arable land. The map shows absolute changes of the area share of arable land compared to the baseline on the NUTS x level in 2025.

Impact on the area covered by grassland. The map shows absolute changes of the area share of grassland compared to the baseline on NUTS x level in 2025.
Example for a change in land use pattern at 1km grid resolution as a result of decreasing agricultural area

Bakker and Verburg 2009
The demand for land use supporting human health and recreation is expected to increase in light of demographic change in Europe.
**SENSOR Clippings**  
Environmental, social and economic indicators (a sample)

**Indicator** | 2025 Baseline Scenario | Effects of CAP Financial Reform in 2025
---|---|---

**Nitrogen dioxide emissions**  
Impact issue: Air quality  
Net impact: Little change  
NOx emissions are highest where there is high population density (traffic and fuel use) and in industrial regions: UK, Belgium, the Netherlands, Germany, parts of Poland, northern France and northern Italy.  
Since NOx emissions are mainly derived from industry and transport, small changes in fuel use in the agricultural sector resulting from agricultural reform do not have a large impact.

**Soil sealing**  
Impact issue: Soil quality  
Net impact: Highly variable, both increases and decreases.  
Soil sealing reflects urban area, and is highest in the industrial and commercial areas of northwest Europe and the coastal regions around the Mediterranean Sea.  
CAP reform creates a highly distributed pattern of change. There are some relatively large changes in urban area (> 5 %), but no consistent patterns across Europe, with adjoining NUTSx regions showing contrasting responses: some increasing and others decreasing.

**Sub-indicator: Total employment of young people (15-24 age group)**  
**Net effect: Slight increase**  
Demographic trend in most European countries is towards relative fall in the percentage of young people (15-24 age group) in the population.  
Abolition of 1st pillar CAP enhances the number of younger people with jobs, but due to negative demographic trend the increase is rather insignificant.

**Deadwood volume**  
Impact issue: Biodiversity  
Net impact: Spatially variable, little change overall.  
Deadwood volume reflects the proportion of standing deadwood in forests and is a biodiversity indicator. Values are highest in Estonia, Latvia and a band across central Europe covering Czech Republic, Slovakia, Germany, Belgium and England.  
CAP reform has relatively little impact on management practices in the forestry sector. There are small increases in some regions across Europe, often balanced by declines in neighbouring NUTSx regions, particularly in England and the Netherlands.

**Greenhouse gas emissions:**  
**Methane**  
Impact issue: Climate  
**Net impact: General improvement, but worsening in some areas.**  
Methane emissions measure only those from agriculture and exclude those from natural habitat. High values reflect high livestock densities, and certain arable landuse types such as wetland rice cultivation.  
There are regional differences across Europe. Moderate reductions occur across France, Spain and parts of Italy, but not in the northern rice-growing regions. The central and eastern EU countries show little change, while parts of Scandinavia, especially Sweden, show increases.
Employment in agriculture | Net effect: Slight decrease, mainly countries which rely strongly on CAP

Over the last decades, the employment in agriculture has been continuously declining in all EU 27 member states. Industrialisation and increased reliance on mechanisation have drastically reduced the need for agricultural labour. Even in the predominantly rural regions, less than a quarter of the total employment is in agriculture, forestry and fisheries. The agricultural sector plays a vital role in preserving the rural landscapes. Thus, it is important to understand how potential policies will affect employment in this sector.

Sub-indicator: Total employment of elderly

Over the last 30 years approximately, there has been a marked reduction in the number of older workers (50+) mainly through the proliferation of schemes for early retirement. In the last few years however, a shift toward later retirement had occurred in order to balance the higher ratio of economically inactive to active population. This trend will according SIAT predictions continue and the number of older workers will increase in most of the EU regions.

Phosphorus (P) surplus:

Impact issue: Water quality
Net impact: General improvement, but worsening in some areas.
P surplus from fertiliser impacts primarily water quality. Values are highest in Belgium and the Netherlands, northern Italy and northern Spain, reflecting areas of high P use in agriculture. Some other intensively used agricultural areas have specific policies to minimise P surplus, e.g., Denmark.

On average, CAP reform reduces P surplus across Europe, with large reductions (>25%) in Romania and France. However, reductions are not consistent across Europe, with many of the Baltic countries showing little change. Some areas also show P surplus increasing by over 25%: Bretagne and Rhône-Alpes in France and parts of Sweden and Finland.

Habitat eutrophication

Impact issue: Biodiversity
Net impact: Improvement.

Habitat eutrophication is a measure of the amount of protected vegetation habitat affected by nitrogen deposition above the critical load. Over half of Europe shows no critical load exceedance, however many countries still have low levels of exceedance. The greatest habitat eutrophication occurs in Belgium, the Netherlands, parts of Germany and northern Italy. CAP reform reduces habitat eutrophication in many of these exceeded areas, especially France and northern Italy. However, there is little reduction in the Netherlands which has the greatest exceedance and nitrogen deposition remains high.
Monetarised impact valuation: Example, nitrogen surplus

The information about potential policy-induced changes in environmental, social and economic indicators may not be enough for a complete evaluation of the policies if externalities are not accounted for. Externalities arise when the action of an economic agent - a firm or an individual - affects the welfare of another economic agent who does not receive compensation for the suffered cost or does not pay for the enjoyed benefit. A framework has been built in to SENSOR to account for externalities. This framework is based on a simplified version of the Impact Pathway Approach (IPA) used in several EC projects (e.g., ExternE). In short, our framework comprises: (a) calculating the physical impact(s) associated with policy-induced changes in the indicators (mainly environmental); and (b) estimating in monetary terms the loss of well-being relative to these physical impacts.

We assessed the range of possible impacts associated with each sustainability indicator and the estimates of the external costs and benefits that were related to those impacts. We have selected external cost and benefit estimates that were generated using sound valuation exercises in Europe or elsewhere.

An example of external costs is provided for nitrogen surplus in the soil. The externalities associated with N-surplus observe a linear relationship with the N-surplus per region estimated within SIAT, since the results of N-surplus (kg/ha) are multiplied by the same range of unit values or external costs. Since N-surplus is associated mainly with agricultural activities and the specific crops cultivated in each region, we could expect higher N-surpluses in predominantly rural areas, with Bucharest, Romania, being the striking exception. The reverse can be expected for predominantly urban areas with economies based on non-agricultural sectors.

External costs in 2025 associated with the change in nitrogen surplus on NUTSx level due to an implementation of the CAP financial reform (100% cut of first pillar budget)

Legend
- Euros per ha
- No data
- 0 - 200
- 200 - 640
- 640 - 1280
- 1280 - 1920
- 1920 - 3200

Ortiz 2009
### Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions

The table shows the NUTSx regions where external costs associated with nitrogen surplus are the smallest and the highest within each country (in €/ha) (2005).

<table>
<thead>
<tr>
<th>Country</th>
<th>Smallest external costs</th>
<th>Highest external costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Region</td>
<td>Lower end</td>
</tr>
<tr>
<td>Austria</td>
<td>Oberösterreich</td>
<td>1.53</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>Dobrich</td>
<td>3.94</td>
</tr>
<tr>
<td>Switzerland</td>
<td>Ticino</td>
<td>17.16</td>
</tr>
<tr>
<td>Czech Rep.</td>
<td>Moravskoslezsky kraj</td>
<td>3.63</td>
</tr>
<tr>
<td>Germany</td>
<td>Dresden</td>
<td>2.38</td>
</tr>
<tr>
<td>Denmark</td>
<td>Storstrøms amt</td>
<td>0.09</td>
</tr>
<tr>
<td>Estonia</td>
<td>Lääne-Eesti</td>
<td>9.22</td>
</tr>
<tr>
<td>Spain</td>
<td>Alava</td>
<td>0.25</td>
</tr>
<tr>
<td>Finland</td>
<td>Pohjois-Pohjanmaa</td>
<td>0.26</td>
</tr>
<tr>
<td>France</td>
<td>Seine-Saint-Denis</td>
<td>0.44</td>
</tr>
<tr>
<td>Greece</td>
<td>Kentriki Makedonia</td>
<td>0.03</td>
</tr>
<tr>
<td>Hungary</td>
<td>Borsod-Abauj-Zemplen</td>
<td>6.05</td>
</tr>
<tr>
<td>Ireland</td>
<td>West</td>
<td>42.03</td>
</tr>
<tr>
<td>Iceland</td>
<td>Iceland</td>
<td>40.27</td>
</tr>
<tr>
<td>Italy</td>
<td>Provincia Autonoma Trento</td>
<td>1.01</td>
</tr>
<tr>
<td>Lithuania</td>
<td>Alytaus apskritis</td>
<td>0.59</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>Luxembourg (Grand-Duche)</td>
<td>67.31</td>
</tr>
<tr>
<td>Latvia</td>
<td>Vidzeme</td>
<td>4.44</td>
</tr>
<tr>
<td>Malta</td>
<td>Malta</td>
<td>0.38</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Groningen</td>
<td>3.83</td>
</tr>
<tr>
<td>Norway</td>
<td>Troms</td>
<td>0.87</td>
</tr>
<tr>
<td>Poland</td>
<td>Opolski</td>
<td>0.72</td>
</tr>
<tr>
<td>Portugal</td>
<td>Centro (P)</td>
<td>3.40</td>
</tr>
<tr>
<td>Romania</td>
<td>Valcea</td>
<td>0.28</td>
</tr>
<tr>
<td>Sweden</td>
<td>Västernorrlands län</td>
<td>9.19</td>
</tr>
<tr>
<td>Slovenia</td>
<td>Slovenija</td>
<td>0.04</td>
</tr>
<tr>
<td>Slovakia</td>
<td>Banskobystricky kraj</td>
<td>20.12</td>
</tr>
<tr>
<td>UK</td>
<td>West Wales and The Valle</td>
<td>0.39</td>
</tr>
</tbody>
</table>

Note 1: External cost = N-surplus per region (kg/ha) times unit value of external cost (€/kg), adapted from Soderqvist (1995), adjusted for year 2005, and transferred to each NUTSx region considering income differentials between regions.

Note 2: Data not always available for all regions within a country.

CAP financial reform scenario: 100% cut of first pillar measures; re-investment of savings in research and development.

Ramon Ortiz (University of Bath)
Forest fire risk

Forest fires are often of anthropogenic origin and the risk of fire is strongly determined by climatic conditions. However, land use influences the likelihood and scale of forest fires by affecting fuel load, vegetation type and landscape patterns. Within SENSOR, forest fire risk was estimated based on changes in tree species composition, the amount of fine and coarse woody litter in forests, forest management intensity, and abandonment of agricultural land as projected by different models included in the Sustainability Impact Assessment Tool (SIAT).

SIAT simulation on the financial reform of the EU budget examines the impacts of abolishing financial support to the agricultural sector for the post-2013 financial perspective. In the simulations, market support and direct farm income support is abolished and all saved funds are re-invested into research and development. Due to these financial reforms, the forest fire risk is projected to increase in many regions across Europe, including regions in Southern Europe which already experience a high forest fire risk due to the climatic conditions.

The main reason for an increasing forest fire risk is due to a reduction of agricultural land. Results of SIAT simulations demonstrate that abolishing CAP support results in a decline of the agricultural land area across Europe. Consequently, this leads to an increasing area covered by shrubs and (young) forests due to natural succession. Both shrub lands and young forests are known to be among the land cover types associated with a high risk of forest fire, because easily burnable materials, such as foliage and thin branches, are close to the ground. This greatly contributes to the risk of a small ground fire developing into a more devastating forest fire.
Baseline scenario: 
Forest fire risk due to climatic conditions for NUTS x regions for 2025

CAP financial reform scenario: 100% cut of first pillar measures.
Impact on forest fire risk on the NUTS x level for 2025

Verkerk and Lindner 2009
(based on data provided by Marco Moriondo)
Impacts on employment

Employment is fundamental to economy and society in terms of income, but it also contributes to social capital, social networks and social inclusion. While employment has increased significantly in the EU since the mid-1990s, the situation is not uniform across the EU 27. There are many “problem regions” and “problem sectors” which lack employment potential. SIAT simulation of financial reform of the EU budget examines the impacts of abolishing financial support to the agricultural sector for a post-2013 financial perspective. In these simulations, market support and direct farm income support is abolished and all saved funds are re-invested into research and development. SIAT examines social impacts of the potential reform on employment of various social groups.

According to SIAT predictions, the total employment will increase in most of the EU countries, on average by 1.2% in effect of a CAP reform. The last decade’s trend of a substantial increase in the number of employed women will be further reinforced. According to SIAT there will be an average increase of 1.3% in the number of employed women.

Over the last 30 years or so there has been a marked reduction in the number of older workers (50+) mainly through the proliferation of schemes for early retirement. In the last few years, however, a shift toward later retirement has occurred in order to balance the higher ratio of economically inactive to active population. According to SIAT, this trend will continue and the number of older workers will increase in most EU regions.
The agricultural sector plays a vital role in preserving rural landscapes. Over the last few decades, employment in agriculture has been continuously declining in all EU 27 Member States. Industrialisation and increased reliance on mechanisation have drastically reduced the need for agricultural labour. According to SIAT predictions picturing the effects of the CAP reform, declining agricultural employment will continue in the future as well. The profound decline in employment in the agricultural sector is expected already in the baseline scenario (-9%, on average). An additional -3% decline corresponds to the effects of the calculated CAP reform.

The employment of elderly in the agricultural sector will decrease by an average of -1%. Further, the employment of young people (15-29) will only slightly be affected by a financial reform of the CAP (average change, -0.3%), whereas the number of women employed in the agricultural sector would decrease, on average, by 3%.

Drillet and Farrington 2009

Impact on the number of employed persons in the agricultural sector. The map shows the deviation to the baseline in % for the year 2025
A landscape identity indicator has been developed for Europe which enables expressing the impact of land use change on cultural and aesthetic values related to regionally specific landscape patterns. Traditional agricultural systems can maintain landscape patterns.
Impacts on alpine regions

Agriculture and forestry are important for the social and economic development of rural regions particularly in the mountains. Not only do they contribute to the socio-economic development by providing jobs, but they also maintain the cultural heritage and traditions relevant to the tourist business in the Alps. The European Union Common Agricultural Policy (CAP) was designed to address the agriculture and forest sector to ensure the sustainable development of these mainly rural areas. Cattle farming and pastures in combination with income from forest management are key elements of multifunctional development in the Alpine regions. The combination of agricultural production areas, forest, and — in some areas — summer as well winter tourist business, ensure the sustainable regional development of the Alps.

The SIAT simulation of the CAP reform shows different regional trends: (i) the development of arable land suggests a moderate decline in the Alpine regions, while (ii) a severe decline in pasture land is predicted across all regions. Agricultural land will be continuously replaced — besides some minor areas for infrastructure and housing — by forests, resulting in a substantial increase in the percentage of forest covered land area. It is important to note that most of the currently used farmland was covered with forests and the forests will have to reinvent their former living space. The main reasons for this development are: (i) a decrease in jobs and income for small farmers resulting in a closing of farms and declining population in rural Alpine areas, and (ii) a change of the main income of farmers particularly in the tourist areas. This also leads to closing of farms.

As a result of this development, we see a substantial increase in the forest covered land area across the Alps. In Austria, the forest covered land area increased by 3.2 % between 1961-2000 resulting in 47 % forest land cover. Similar tendencies of a decline in agricultural land and pastures but increasing forests are evident for Bavaria, Switzerland, northern Italy and France. For example, in Switzerland, the forest land increases by 0.4 % each year. Bavaria reports an increase of currently 420 ha each year and in Austria the forest covered land increases by 7,500 ha per year. A continuation of this trend can be anticipated since the steep alpine farming conditions cannot compete with the very productive, flat and excellent agricultural conditions as evident in most of the new EU member states. An interesting development in this context is the expected need for biomass and biomass production as an alternative income for farmers. The replacement of farm land by forests and its use for bioenergy production may be one of the interesting new income sources for former rural farming areas.
Functions of land use

Why Land Use Functions?

We wanted to assess the impact of policies on land sustainability in a comprehensive way across regions. We realised that this was not possible using individual indicators since different indicators might be used per region. Farmland birds, for instance, can be an indicator for biodiversity in most European regions. However, in Malta this is not suitable because no farmland birds exist. Focusing on the function of the land associated with biodiversity — in this example provision of biotic resources — allows a consistent cross-cutting comparison between the situations in Malta and the UK.

What are Land Use Functions?

We defined Land Use Functions as the goods and services provided by the different land uses that summarise the most relevant societal, economic and environmental issues of a region. Following expert consultations, three key functions linked to the use of the land were identified for each of the three sustainability dimensions. For societal issues: provision of work, human health and recreation, and cultural functions; for economic issues: residential and land independent production, land-based production, and transport infrastructure; and for environmental issues: provision of abiotic resources, provision of habitat, and ecosystem processes maintenance. Using the nine Land Use Functions, we simultaneously consider the positive and negative impacts that changes in land use have on land functions. For example, the indicator “soil sealing” (e.g., construction of new buildings) might create employment and therefore have a positive impact on “provision of work”, but at the same time decrease the Land Use Function “provision of habitat”.

Can a political decision ever be sustainable?

There are two sides to every coin. The same is true for sustainability. A decision can be sustainable according to objective results of impact assessment based on current knowledge. The results provide an objective value that lies above or below a sustainability limit. On the other side, the decision depends on the subjective interpretation of the individuals involved. For example, CO₂ emissions might exceed critical levels according to scientific evidence, but not according to the interpretation of critical levels by individual decision-makers, as was shown at the Kyoto summit in 1992.
The Land Use Functions can be applied on any spatial scale, from local (NUTS2/NUTS3, average area of 8000 km²) to regional, national or even EU. The approach is flexible and can be used either for desk analysis based on scientifically measured indicators, or adapted for examining land use trade-offs in stakeholder workshops (as was done in SENSOR).

This was often discussed during the project. The concept of ecosystem services mainly focuses on the environmental functions, whereas Land Use Functions considers the three dimensions equally. Ecosystem services consider the individual impact of indicators whereas Land Use Functions consider the cross-linkages and provide an integrated assessment. The main issue with ecosystem services is that key issues for the main actors, the human beings, might be forgotten and the concept, therefore, might not work in reality. In order to avoid this, I prefer taking into account all three dimensions of sustainability already in the course of decision-making.

It seems true that policy-makers are moved a lot by economics, but they need to trust the way an economic assessment has been done. Following the example of monetary valuation of ecosystem services, at the current state of research, monetary valuation is only useful for certain issues such as air pollution. Scientifically, the issues are still poorly grounded causing politicians not to trust them. In addition, there are some services that simply cannot be measured, which does not mean that these functions do not need to be taken into account. Finally, monetary valuation is calculated for a specific location in a specific context, meaning that it is not easily extrapolated in time and space. Therefore, I do not think that monetary valuation will provide an added value to the Land Use Functions.

<table>
<thead>
<tr>
<th>Mainly Societal Land Use Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Provision of work: employment provision for all activities based on natural resources, quality of jobs, job security, and location of jobs (constraints, e.g., daily commuting)</td>
</tr>
<tr>
<td>2. Human health &amp; recreation (spiritual &amp; physical): access to health and recreational services, and factors that influence service quality</td>
</tr>
<tr>
<td>3. Cultural: landscape aesthetics and quality, and values associated with local culture</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mainly Economic Land Use Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Residential and land independent production: provision of space where residential, social and productive human activity takes place in a concentrated mode. The utilisation of the space is largely irreversible due to the nature of the activities.</td>
</tr>
<tr>
<td>5. Land-based production: provision of land for production activities that do not result in irreversible change, e.g., agriculture, forestry, renewable energy and land-based industries such as mining</td>
</tr>
<tr>
<td>6. Transport infrastructure: provision of space used for roads, railways and public transport services, involving development that is largely irreversible</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mainly Environmental Land Use Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Provision of abiotic resources: the role of land in regulating the supply and quality of air, water and minerals</td>
</tr>
<tr>
<td>8. Provision of habitat: factors affecting the capacity of the land to support biodiversity, in the form of the genetic diversity of organisms and the diversity of habitats</td>
</tr>
<tr>
<td>9. Maintenance of ecosystem processes: the role of land in ecological supporting functions such as soil formation and energy buffering</td>
</tr>
</tbody>
</table>
Regional impacts on Land Use Functions

Indicator trends show a considerable variability across EU27, and do not provide an integrated picture of the impact of the CAP scenario on land use sustainability. Therefore, we use the Land Use Functions (LUFs) as a tool to assess the impact of policies in a comprehensive way across regions. To exemplify the Land Use Function approach, we selected two regions, that both have a high degree of rurality but very different bio-physical and socio-economic characteristics.

Jaén is a province of southern Spain, in the eastern part of the autonomous community of Andalusia. Jaén consists of mainly rural and remote areas with few cities. It is one of the larger producers of olive oil in the world. At present, olive oil production is heavily subsidised by CAP. This policy has led to intensification and increased output with generally negative consequences for the environment. On the other hand, it has helped to reduce the land abandonment in marginal regions.

Etelä-Savo (Southern Savonia) is a region in southeast Finland. It is located in the heart of the Finnish lake district. It has only two major towns in the region, the rest being mainly rural or remote areas. Its key economic sectors are services (67%) and manufacturing (24%), with a minor role of the primary sector (9.2%). Because of the climate, agricultural development is limited to maintaining self-sufficiency in basic products. Forestry, an important export earner, provides a secondary occupation for the rural population that suffers from a high unemployment rate (12%). Under current arrangements, Finland receives a relatively low rate of direct support per hectare of utilised agricultural area under pillar 1 of the CAP compared to other Member States.

Jaén. A province in southern Spain.

Scenario: CAP financial re-form scenario: 100% cut of first pillar measures; re-investment of savings in research and development

Impact on Land Use Functions. The diagram shows Land Use Function scores for baseline and CAP reform scenario in 2025

Perez Soba and Jones 2009
The regional impact of a financial reform of CAP is compared with the business as usual scenario and with reference to the regional sustainability limits. Sustainability limits are defined in SENSOR as the unacceptable damage of a pressure on a social, economic or environmental system. The effect of a policy may improve a Land Use Function value relative to the sustainability limit, or move the LUF value to the wrong side of the limit. The two spider diagrams below show that impacts differ in the two regions.

Overall it can be seen that in Jaén, a region with high first pillar CAP payments, the impact of the CAP reform will result in a decrease in the provision of work and in the support and provision of biotic resources, both of which are already below the sustainability limits. There will also be a decrease in one of the environmental Land Use Functions: support and provision of biotic resources. A decrease in the provision of habitat (as part of the support and provision of biotic resources) might be associated with resulting abandonment of traditional olive plantations that are of highest natural value for biodiversity and landscape. On the other hand, the heterogeneity of the landscape and thus the cultural and aesthetic value will increase, as will the transport infrastructure.

The patterns of the spider diagram show that the impact of the CAP scenario will be quite different in Etelä-Savo, a region that currently benefits from a low rate of first pillar CAP support, but a high degree of technological development. The reinvestment in research and development will result in a general increase in the provision of work. In addition, the abolishing of the first pillar CAP support will result in more urban area (land independent production) and, consequently, transport infrastructure as new urban area needs to compete less with agricultural land that would become cheaper when the CAP is not maintained.
Though regionally differentiated results are predicted, reductions in CAP support will not considerably affect the overall European trends for the provision of abiotic resources, such as water, air and soil quality. However, hot spots related to the intensity of land use might occur.
European regions are facing sustainability issues that differ both in type and intensity. SENSOR partners have always recognised the need to develop complementary approaches and methodologies. FoPIA, the Framework for Participatory Impact Assessment, involves national, regional and local stakeholders in assessments of land use policy impacts. FoPIA’s design is structured around the same logical framework that defines the design parameters of the model-based SIAT – the EEA Driver-Pressure-State-Impact-Response framework.

FoPIA is not intended to replace, but to complement the technical, model-based analysis of policy impacts. The stakeholder-inclusive research developed within SENSOR performs a revelatory function, purposefully complicating the technical analysis of policy impacts and reminding us that not only are the outcomes of cause-effect processes difficult to predict, but that combinations of social, economic and environmental responses may set in train subsequent, and equally complex interactions that could not have been envisaged from the outset and which, therefore, could not have been represented in the knowledge rules that govern the model-based calculations.

FoPIA should be interesting to stakeholders from an analytical perspective, since it allows assessing policy impacts accurately considering the relationships between environmental, economic and social issues and to inform about unavoidable trade-offs, compromises and possible win-win situations. However, the application of FoPIA involves workshops with stakeholders from a given region. Working through an impact assessment by discussing plausible policy scenarios gives stakeholders the opportunity to share insights with colleagues. We have found that many participants are very interested in the methodology and can see ways of applying some of the methodological approaches in their own work.

In general, the collective experience of the researchers involved in the implementation of FoPIA across five sensitive area case studies and two policy cases has been extremely positive and the team is happy and proud to commend the FoPIA to the European Commission. While participatory approaches are nothing new, the Framework for Sustainability Impact Assessment of policies in European regions required a significant amount of innovation and adaptation. On reflection, a satisfying aspect of developing FoPIA has been the growing realisation that it has a very useful role to play in improving both the accuracy and the legitimacy of sustainability impact assessment in Europe.
FoPIA analytical chain

FoPIA (Framework for Participatory Impact Assessment) is a tool for sustainability impact assessment, though not a computer tool. Detailed stakeholder-inclusive research facilitated by FoPIA can add to the analytical scope beyond SENSOR by identifying the limitations of a mechanistic, data-driven approach, and by indicating where additional capabilities need to be developed. It also provides some working examples of research methodologies that could be used to fill the gaps left by the models currently available for SIA.

The analytical structuring of FoPIA allows an iterative approach to assessing the impacts of policies in a way that is sensitive to national and regional sustainability priorities a key requirement of the SIATs produced by the SENSOR project. Firstly, it enables the assessment of policy scenarios that are likely interpretations of EU policies informed by knowledge of specific sustainability problems. Secondly, it ensures that predictions of the resulting changes in land-use are sensitive to the socio-economic, cultural, political and legislative contexts of local and regional land use. Thirdly, it enables the selection and analysis of sustainable land use criteria and indicators which reflect key local and regional sustainability issues. Lastly, the analysis of the acceptability of impacts and the discernment of “room for manoeuvre” is informed by stakeholders’ knowledge of the current status of economic, social and environmental resources. This logical flow from problem definition through scenario development, the analysis of criteria and impact assessment, to sustainability impact assessment and the central role of stakeholders in driving the analysis in each of the sequenced steps is illustrated below.
While FoPIA, like the model-based SIAT, is structured around the DPSIR framework, there are a number of significant differences between the two approaches both in terms of their design and application. Of critical relevance here is the issue of scale and the fact that SIAT operates as a macro-level tool designed to produce generalisable predictions of policy impacts for the whole of Europe. As such, to function efficiently, a number of analytical components, such as the indicator framework, the response functions governing the relationship between sustainability indicators and land use change, and the sustainability limits for each indicator, are “hard-wired” into the model chain. In contrast, FoPIA is a micro-level tool used to generate results that may be specific to a defined geographic, socio-economic and environmental context. As such, analytical components, such as indicators, response functions and limits are not pre-defined, but become the subject of discursive analysis during each phase of stakeholder engagement. However, these differences in approach between the two tools are not merely accidental. They are the result of a considered process of FoPIA design where the intention is to produce an alternative methodological framework for sustainability impact assessment that will enable the constructive problematisation of its model-based cousin. This gives the end-user the ability to visualise and to “ground truth” SIAT outputs and to highlight instances where judgements of sustainable or unsustainable land use futures fail to reflect sustainability issues and problems particular to a given region.

“...dividing the holistic concept of sustainability into three pillars ...runs the risk of the sum of the parts being less than the whole. This is particularly true if the interrelations between the three pillars are not adequately understood and described...” (Gibson, 2001: 12).

FoPIA mini manual

FoPIA is process-oriented. It supports discussion among stakeholders, key players and decision makers providing a discursive space for the exchange of knowledge. FoPIA is also results-oriented. It aims to produce knowledge about the potential application and consequences of proposed policy changes. For each policy case, detailed questions lead the participants through the steps of an impact assessment.

**Phases 1 and 2: Scenario definition**
- **Identify regional specifications**
  
  The first objective is to produce nationally and regionally relevant policy scenarios. This requires an analysis of the sustainability issues, national interpretations and implementations of European policy and policy instruments that are likely to be adopted. The scenario definition involves structured interviews with national and regional-level policy-makers and experts and the analysis of policy documentation and structured interviews with staff from the regional offices of government departments, those involved in spatial planning and decision-making, representatives of relevant land use sectors, members of landowner interest groups and landowners.

**Phases 3 and 4: SIA workshops**
- **Discussion and analysis**

  The results of the stakeholder valuation show the relative importance of Land Use Functions. The attribution of perception is done by the group valuation method, allowing the quantification of preferences, which then provide the first point of discussion in the stakeholder workshops. The workshops are structured around five sequenced “sessions”, each yielding results which provide the inputs for the subsequent session. These workshops can be organised as a one-day event, or as two half-day events. Additional participants with particular knowledge, experience or expertise relating to the policy case, the relevant economic sectors, land use, or sustainability issues can also be invited.

**Workshop Session 1** ➔ **Refining the scenarios**

**Workshop Session 2** ➔ **Analysing the criteria (no trade-off)**

**Workshop Session 3** ➔ **Impact assessment**

**Workshop Session 4** ➔ **Sustainability limits**

**Workshop Session 5** ➔ **Analysing the criteria (with trade-off)**

**Workshop wrap-up session**

FoPIA is subsequently applied to an analysis of “states” (changes in social, environmental and economic systems as evidenced by indicators), “impacts” (the acceptability of the changes), and “response” (the analysis of sustainability criteria provides a basis for decision-makers to interpret the SIA results).
FoPIA Policy scenario: Bioenergy – a solution worth promoting?

The EU is committed to combating climate change and increasing security of its energy supply. The two main objectives of the Renewable Energy Road Map of the EU are increasing security of energy supply and reducing greenhouse gas emissions. The EU has faced differentiated discussions recent last years on how these goals can be achieved in a sustainable way. Bioenergy is one of these renewable energy sources.

The principal objectives the EC will attempt to achieve in bioenergy are: (1) quantitative targets for the proportion of bioenergy in the three categories of energy output (transport fuels, electricity and heat), (2) sustainability of production, and (3) fostering a competitive bioenergy industry (also for export purposes) through technology development.

From the options described above, two policy variables have been selected to reflect the main options open to European policy-makers:

1. Promotion of bioenergy production and consumption in the forms of:
   a. a mandatory percentage of biofuel in transport
   b. subsidies for research and development of bioenergy in all its forms
   c. subsidies (including tax breaks) for the production of heat and electricity from biomass

2. Modifying current restrictions on imported biofuels, thus allowing tariff-free importation of ethanol and enabling the substitution of rapeseed and sunflower oil by various cheaper imported vegetable oils for the production of biodiesel

Agriculture and forestry are the two major sectors providing raw material for renewable energy production. Hence, any bioenergy policy will have an impact on land use and subsequently on the sustainable development of rural areas and use of natural resources. However, in recent years it has become evident that the assessment of side-effects of an increased energy-crop production is needed to identify the most suitable policy measures.
**Silesia: Influence of bioenergy policy scenarios**

### Bioenergy promotion policy scenarios in Silesia

<table>
<thead>
<tr>
<th>Scenario 1: Low promotion</th>
</tr>
</thead>
<tbody>
<tr>
<td>- There are no biofuel production obligations</td>
</tr>
<tr>
<td>- There are no renewable energy sources production obligations</td>
</tr>
<tr>
<td>- Bioenergy crop area does not change</td>
</tr>
<tr>
<td>- No specific financial support</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 2: Medium promotion</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Biofuel production obligations met</td>
</tr>
<tr>
<td>- Renewable energy sources production objectives met</td>
</tr>
<tr>
<td>- Bioenergy crop area increases slightly</td>
</tr>
<tr>
<td>- Financial support (subsidies, reduced taxes) are effective</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 3: High promotion</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Biofuel production obligations increased</td>
</tr>
<tr>
<td>- Renewable energy sources production objectives increased</td>
</tr>
<tr>
<td>- Bioenergy crop area significantly increases</td>
</tr>
<tr>
<td>- Financial support (subsidies, reduced taxes) are very effective</td>
</tr>
</tbody>
</table>

Programmed changes in the energy sector are expected to be especially important to Silesia, one of the SENSOR sensitive case study areas and a characteristic coal mining region. As such, the promotion of alternative sources is likely to have important consequences for sustainable development in the region. In SENSOR, experts and stakeholders met to assess the likely regional impacts of policy-driven support for bioenergy. Three scenarios were discussed.

A low promotion scenario for biofuels in Silesia was devised as a baseline. An alternative scenario followed the assumption that bioenergy cropping area will need to increase to meet current obligatory targets of the EU. A high promotion scenario represented the situation characterised by intensive development of the bioenergy sector, with a substantial and unregulated increase in the area dedicated to bioenergy crop production. Experts noted that the status quo, in terms of both policy implementation and land use, sits somewhere between scenarios 1 and 2. They commented that Poland had only recently implemented a national bioenergy policy.

Overall, the analysis of limits reveals that notably high sustainability standards were set by the stakeholder group, which may reflect the serious nature of the sustainability problems currently faced by the region. The regional performance of any change in policy is therefore likely to be judged against these standards.

Of note is the fact that a moderate increase of bioenergy cropping area would have a predominantly positive impact on Land Use Functions. Apart from biodiversity, where the group predicted a slightly negative impact on species population numbers as a result of changes in crop structure, the scenario would have significant positive impacts regarding social criteria with a high preference rating (e.g., employment and public health). However,
the impacts of scenario 2 show that sustainability standards will not be reached (with the exception of “visual attractiveness”), which is perhaps more of a reflection that very high sustainability standards were set by the group, implying that all dimensions of sustainability need substantial improvement in Silesia.

The largest differences between impacts can be observed for an intensive growth of bioenergy crop area. This scenario would greatly increase employment and production in agriculture, but it would have strong negative impacts on the efficiency of the road network and on biodiversity.
Stakeholders’ perception of land use functions

Stakeholder analysis plays a central role as stakeholder opinions, values and preferences need to be taken into account when making policy decisions. In order to find out whether stakeholders understand and value the Land Use Functions and how they see land use related sustainability issues, their preferences have been assessed using a European internet survey. This internet survey, carried out in Italy in 2008, asked 394 respondents to express their own preferences toward different Land Use Functions that are balanced towards the three pillars of sustainability (social, economic and environment) using a five-point Likert scale per Land Use Function. The response frequencies show that all Land Use Functions are valued as important to different degrees. Indeed, the mean Likert scores for each Land Use Function range between 3 (indifference) and 4 (quite important) to 4 and 5 (very important).

A pattern seems to emerge from the data. Moving from economic to social to environmental Land Use Functions, the scores become higher and more accurate. However, at first glance the relative weights do not seem very different from each other. Therefore, the data collected in Italy supported the assumption that each sustainability pillar should be equally weighted. The normalised weights of the Land Use Functions belonging to the same pillar of sustainability (table 1) resulted in the following weights per pillar: economic = 0.308, social = 0.332, and environmental = 0.360. These are, indeed, not so far from the hypothesised weights of 1/3 each.

Internet survey on perceptions of Land Use Functions. The table shows the value scores (means, standard deviations and normalised weights) for nine Land Use Functions

<table>
<thead>
<tr>
<th>Sustainability Pillars</th>
<th>Land Use Functions</th>
<th>Means</th>
<th>Std. Dev.</th>
<th>Normalised weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECO</td>
<td>Residential and land independent production</td>
<td>3.47</td>
<td>1.121</td>
<td>0.091</td>
</tr>
<tr>
<td>ECO</td>
<td>Transport infrastructure</td>
<td>3.80</td>
<td>0.897</td>
<td>0.100</td>
</tr>
<tr>
<td>ECO</td>
<td>Land-based production</td>
<td>4.44</td>
<td>0.701</td>
<td>0.117</td>
</tr>
<tr>
<td>SOC</td>
<td>Cultural</td>
<td>4.10</td>
<td>0.856</td>
<td>0.108</td>
</tr>
<tr>
<td>SOC</td>
<td>Human health and recreation</td>
<td>4.14</td>
<td>0.818</td>
<td>0.109</td>
</tr>
<tr>
<td>SOC</td>
<td>Provision of work</td>
<td>4.38</td>
<td>0.705</td>
<td>0.115</td>
</tr>
<tr>
<td>ENV</td>
<td>Support and provision of biotic resources</td>
<td>4.53</td>
<td>0.738</td>
<td>0.119</td>
</tr>
<tr>
<td>ENV</td>
<td>Provision of abiotic resources</td>
<td>4.54</td>
<td>0.706</td>
<td>0.119</td>
</tr>
<tr>
<td>ENV</td>
<td>Maintenance of ecosystem processes</td>
<td>4.64</td>
<td>0.685</td>
<td>0.122</td>
</tr>
</tbody>
</table>

A pattern seems to emerge from the data. Moving from economic to social to environmental Land Use Functions, the scores become higher and more accurate. However, at first glance the relative weights do not seem very different from each other. Therefore, the data collected in Italy supported the assumption that each sustainability pillar should be equally weighted. The normalised weights of the Land Use Functions belonging to the same pillar of sustainability (table 1) resulted in the following weights per pillar: economic = 0.308, social = 0.332, and environmental = 0.360. These are, indeed, not so far from the hypothesised weights of 1/3 each.
Changes in infrastructure are not directly connected to the SENSOR policy scenarios. However, scenarios forecast considerable increase in GDP when financial support to agriculture is reduced and shifted to research and development. This could lead to increasing needs for transportation.
Malta: The local aspect of sustainability impacts

Expert interviews and stakeholder focus groups defined three key factors that determine land use change in Malta: land development, the level of protection of natural resources (such as biodiversity and water) and the challenge of maintaining competitiveness in an increasingly globalised economy. The consensus on selecting biodiversity as a policy case for Malta demonstrates the high concern of the Maltese policy community for the protection of natural resources, and the high level of awareness towards the inter-linkages of land development, climate change and challenges faced by the agriculture sector.

Three policy scenarios were discussed in detail: a baseline scenario, a medium protection scenario and a high protection scenario. After an introduction of the concept of Land Use Functions, a preliminary list of sustainability criteria was discussed. Based on these criteria, the Land Use Functions were then scored, calculated and adjusted. Researchers noted that there was significant uniformity across all Land Use Functions with slightly higher importance attached to environmental criteria than to economic and social. This suggests that, unconstrained by the trade-offs implied by the results of the impact assessment process, the stakeholders tended not to prioritise certain criteria over others.

It was interesting to note that the majority of stakeholders placed great importance on specific environmental protection criteria during the workshops, highlighting the necessity of a high degree of biodiversity protection in the Maltese Islands. A surprising result, perhaps, is that stakeholders forecasted an increase in the value of agricultural outputs under the high protection scenario and a fall under the baseline scenario. The result was examined by the research team, and stakeholders explained that, under the high protection scenario, farmers would be more likely to diversify their production base, and to explore and exploit specialist niche markets within the agro-industry sector, thereby increasing the financial value of their products. For example, agricultural products such as woollen clothing, and similar products, might be produced for the tourist market.
In the final session, the focus of the analysis returned to the assessment criteria in order to elicit stakeholder preferences. Participants were asked to assess the relative importance of each criterion in terms of sustainable land use in Malta.

A simultaneous view of impacts, limits and ranking score provides extremely valuable information to the decision-maker trying to decide between different policy scenarios. Importantly, the results for Malta show that the high protection scenario achieves positive impacts in relation to highly prioritised criteria and performs best in terms of the minimum sustainability standards for each indicator.
Except for beef, the amount of agricultural land-based production will not change considerably, even if farm income support and market support in the financial reform of the CAP are set to zero.

Land-based Production
The consequence of being an island

Post-industrial zones, mountains, coasts and islands are particularly sensitive to significant changes in terms of key economic, social and economic issues. Policy measures taken on the European level may have a stronger impact in these areas compared to other parts of Europe. In the European Union and in particular in new Member States, those areas deserve specific attention in impact assessment. SENSOR research confirmed that sensitive areas might react differently to programmes, European regulations or European policies in general. Thus, an understanding of local and regional specificities is essential for testing the robustness and relevance of the Sustainability Impact Assessment Tools (SIAT).

Malta joined the EU in 2004 and was selected to represent the particular characteristics of European islands, often at the periphery of policy designing and policy-making decisions. With extreme population dynamics, higher costs and difficult access to certain goods and services due to insularity, Malta suffers clear constraints that are generally common among European islands.

The most important sustainability issue was the correct management of the land resource. There is a natural conflict between the necessity to have basic vital facilities such as airports, harbours, a national stadium, housing area and the amount of land available. At the end of the day, these activities must take place on a limited territorial space. The issue of nature protection emerges particularly in the context of fear of losing an environment in which to spend recreational time, as well as losing biodiversity and cultural heritage, and the threat of climate change.

We selected the biodiversity policy case as an example of participatory impact assessment, since it nicely summarised many sustainability issues previously identified. The results of our intense work and the high commitment of stakeholders led to a clear result, where a high protection of biodiversity would be beneficial to all sectors. The management of natural resources is linked with management of water, waste and land resources, as well as the conservation of cultural heritage. Finally, the relevance of the scenario was particularly high in the context of climate change.
Earlier, we were involved in scientific networks with Argentina and Uruguay, devoted to studying land use change processes and impacts with a focus on the biophysical dimension. In SENSOR TTC we tested the transferability of methodological concepts such as the technical implementation of SIAT. The reaction to presentations of the project was very positive and at the moment I would say decision-makers are observing our activities with interest.

Research focused on oil price, demography and GDP dynamics are all linked to main land use change processes. Regarding the policy cases, we selected two: sugar cane expansion and afforestation for timber, paper and cellulose production. Sugar cane expansion is directly related to demography, demand for energy and dependence on fossil fuels. The climate change phenomenon has increased the demand for non-fossil fuel based technologies and we project an increasing demand for such energy, thus expecting further growth of sugar cane production. The second policy case concerned with afforestation for timber production is very exciting because it involves the three countries (Brazil, Argentina and Uruguay) and is therefore even better suited to check the transferability of the SENSOR approach.

The baseline scenario with no political intervention shows an expansion of sugar cane cultivation in Mato Grosso do Sul from 2008 to 2017. The alternative scenarios consider governmental regulation by means of zoning as a policy instrument as stipulated in the 2006-2011 Brazilian Agro-Energy Plan. The first alternative scenario assesses the impact of government incentives for sugar cane expansion areas previously used as pastures. A second alternative scenario considers the expansion of sugar cane in areas also formerly used for growing grain crops.

There has been a lot of interaction with the partners from the SENSOR consortium, including the exchange of post-docs, training and conceptual meetings. A lot of communication was conducted at the beginning, and now the perspectives for the continuation of exchange and cooperation are very good. I would add that the linkage between Mercosur and China, although not one of the objectives, is an important add-on. An exchange between Europe and China and between Europe and Mercosur was expected and planned, but the closing of the triangle through an exchange between Mercosur with China is something we are very much looking forward to now. In my opinion, Europe has a lot to gain from the further involvement of all three continents.
The provision of biotic resources is very sensitive to land use changes. Indicators linked to highly intensive agricultural production such as farmland birds are particularly sensitive to the changes in CAP. Indicators that are linked to the occurrence of landscape in general, such as landscape cohesion, will not change significantly with CAP changes.
Almost all SENSOR EU approaches and components have been tested in China, where the methodologies were found to be very useful for sustainability assessments of multifunctional land use. The analytical method of the Spatial Regional Reference Framework, for instance, was applied to cluster the entire country into 9 regions and 157 clustered sub-regions, which represent basic spatial units for land use and functional analysis. The scenario approach consisting of a baseline scenario, policy scenarios and land use functions (LUFs) was adopted for tracking ex-ante land use changes and its impacts on regional sustainable development. The results the spatial and temporal dynamics of the Land Use Functions – were very useful in developing regional specific development strategies.

SIAT-China is now being developed by adapting structures, frameworks and major research findings. The results of a comparison between SIAT-EU and SIAT-China were demonstrated to research experts, governmental officials and decision-makers at the national and local levels during field visits with a very positive feedback. Great interest was shown for the application which supports scientifically sound and practically transparent decision-making. The challenge now is to find out to which extent the research findings can be integrated into the decision-making process and how it would be done best.

Researchers and officials participated in selecting four drivers and three policy cases for the case study in China. The driving forces of ex-post land use change include population growth, urbanisation, number of cars owned per 1,000 persons and research and development investment in agriculture. Policy cases include slope land conversion policy concerning environmental conservation through reduction of cultivation on slopes and hilly land; bio-energy use which is closely linked to emission reduction and, hence, environmental protection; and agricultural subsidies for farmers to avoid land abandonment.
Low growth, medium growth and high growth scenarios for land use changes in China have been designed at the 10 km grid pixel level for the next two decades (2005 to 2025). The simulation results indicate that while forest area is expected to expand at a moderate speed and cultivated land will decrease, both built-up area and forest area will increase dramatically, and the water body will remain relatively stable for the next two decades. The northeastern and northwestern parts of China contain zones sensitive to land use changes. Policy scenarios have a relatively stronger impact on land use changes than baseline scenario, as indicated by the area of land use changes. The simulation results under various scenarios are of great importance to simulate the dynamic changes of land uses, which can provide valuable information for decision-making on land management and land use planning.

SENSOR has served as a very good platform to bring scientists and decision makers from the EU, Mercosur and China together to share their knowledge and experience. Cooperation led to collaborations including joint project research activities, capacity building and training, exchange of scholars, jointly organised conferences and workshops, as well as joint publications. We are very optimistic that this cooperation will be maintained in the future.
What is the relevance of SENSOR results in a global context?

David Pannell, SENSOR Scientific Peer Group, University of Western Australia

SENSOR has tackled a problem of international relevance and importance: how to predict and evaluate the consequences of policy changes that will affect a range of land use sectors. In addressing this task, the multi-national project team has had to confront substantial challenges across the range of activities undertaken. These challenges have related to science, conceptual issues, data management, computer modelling and project management. The lessons from their efforts to address and successfully overcome these challenges will be of great relevance to other research teams around the world who set out on similar paths. The flow of concepts, methods and approaches to other countries has already commenced, with the project’s successful establishment of partner activities in China and Latin America.

What is the advantage of looking at multifunctional land use?

Franc Lobnik, SENSOR Scientific Peer Group, University of Ljubljana

Europe’s land use management is lagging behind other concerns, such as the protection of water and air. However, the issue is becoming increasingly relevant. In the future I expect a much higher need to produce sufficient high-quality food in Europe in order to avoid transportation costs. Agricultural production is linked with rural development. Keeping people in the countryside requires support not only for agriculture but also for cultural activities, sustainable tourism, room for recreation and conservation.

Already today we must resolve problems of conflicting interests. In some regions of Eastern Europe where infrastructure was not developed well, huge infrastructure projects support development, for example, of highways or speed trains. Meeting demands puts lowlands under tremendous pressure. One conflict concerns protected areas under Natura 2000 and the desire to develop infrastructure. Other conflicts appear, for example, when people from the city move to the countryside, expecting only birds and honey, and not cows and manure.

Multifunctionality of land is a basic issue for sustainable development. The strategy for Sustainable Development should be taken much more serious by European decision-makers.
An internet search for an approach to ex-ante impact assessment for sustainable land use will surely refer to the SENSOR homepage. In the context of land use, SENSOR has become a synonym for ex-ante impact assessment procedures and has lead to a new level of quality regarding decision support systems for the science policy interface. The high number of disciplines involved in producing the ex-ante sustainability impact assessment tools (SIAT and FoPIA) makes it particularly credible. They have become important tools for both scientists and decision-makers.

In my eyes, the innovation of SENSOR lies in the fact that the project brought together various consortia to address the problem of land use management in a sustainable manner across Europe. The impact on policy-making is a tool developed by SENSOR that will help to steer processes towards sustainable land use, especially regarding specific processes such as biomass production, e.g., bioenergy. The biggest challenge is bringing together the relevant components of economic, ecologic and social demands in Europe’s various regions based on a common understanding of land management.

The integration of information from various disciplines has been one of the main challenges of SENSOR. This is very important in terms of policy support. The scientific expert always has his disciplinary background, while the politician will usually ask a more integral question. SENSOR has gone quite far in developing tools to answer to the questions posed.

The question of triviality is always problematic. The data must, of course, be as accurate as possible, in order to not produce misleading results. The judgement if something is of sufficient detail, however, is not on the scientific side. The level of detail and abstraction are determined by the receiver.
The research team

SENSOR was borne by the excellence, professional dedication and interdisciplinary expertise of its partners. The mutual commitment and intercultural enthusiasm made the cooperation a pleasant experience.

Leibniz Centre for Agricultural Landscape Research (ZALF): Katharina Helming, Bettina König, Karen Tscherning, Katharina Diehl, Anke Hollburg, Birthe Schößer, Hannes König, Klaus Müller, Stefan Sieber, Katharina Fricke, Dirk Pohle, Martin Hecker, Hubert Wiggering

Alterra Green World Research: Marta Perez-Soba, Dirk Wascher, Marion Bogers, Sander Mücher, Bas Petroli, Johnny te Roller, Michiel van Eupen, Peter Verweij

Brandenburg University of Technology Cottbus (BTUC): Oliver Dilly, Christian Rogass, Reinhard Hüttl, Frank Repman, Uwe Schneider, Carola Dörrie

ARC systems research GmbH: Wolfgang Loibl, Jan Peters-Anders

Department of Conservation Biology, Vegetation- and Landscape Ecology, University of Vienna: Thomas Wrbka, Christa Renetzeder, Andrea Stocker-Kiss

Institutes of Soil Science and of Forest Growth Research (BOKU): Hubert Hasenauer, Richard Petritsch, Friedrich Putzhuber, Walter Wenzel

Swiss Federal Institute of Forest, Snow and Landscape Research (WSL): Norbert Kräuchi, Janine Bollinger, Dionys Hallenbarter, Felix Kienast

Dept. of Agricultural Economics and Social Sciences, HU Berlin: Konrad Hagedorn, Andreas Thiel, Renate Judis, Martina Padmanabhan

Chair of Forest Yield Science, TU Munich: Peter Biber, Ricardo Acevedo

Aarhus University (AU, NERI, DIAS): Hanne Bach, Henning Sten Hanssen, Tommy Dalgaard, Pia Frederiksen, Niels Halberg, Berit Hasler, Nick Hutchings, Finn Vinther, Morten Tranekjaer

University Copenhagen, Forest and Landscape (UCPH, FLD, KVL): Kjell Nilsson, Berit Charlotte Kaae, Thomas Sick Nielsen, Bernhard Snizek, Erling Andersen

University Tartu (U Tartu): Ülo Mander, Margit Koiv, Ain Kull, Tonu Oja

European Forest Institute (EFI): Marcus Lindner, Andreas Schuck, Hans Verkerk, Sergey Zudin

CEMAGREF Groupement de Grenoble: Nathalie Bertrand, Jean Paul Bousset, Vincent Briquel, Jean-Jacques Collicard, Catherine Macombe

Centre d’Observation Economique (COE/CCIP): Pierre Le Mouel, Paul Zagame

Institute of Environmental Sciences University of Western Hungary (UWH): Éva Konkoly, Tatai Zsombor, Sándor Jombach
Institute of Environmental Management, University Gödöllö (SZIE/KGI): Lazlo Podmaniczky, Norbert Kohlheb

International Institute for Applied System Analysis (IIASA): Isolde Prommer, Wolfgang Lutz, Monica Manchanda

Dept. of Agriculture and Resource Economics of Florence University (DEART-UNIFI): Cesare Pacini, Luigi Omodei Zorini, Donato Romano

Institute for Environment and Sustainability (IES), Ispra (JRC): Maria-Luisa Paracchini, Jürgen Vogt

Plan Making and Policy Development Unit, Malta Environment and Planning Authority (MEPA): Marguerite Camilleri, Stefano Moncada, Keith Cappello, Monique Hili

Agricultural Economics Research Institute (LEI): Tom Kuhlman, John Helming, Kristina Jansson, Torbjörn Jansson, Hans van Meijl

Environmental Systems Analysis Group and Land Dynamics Group, Wageningen University (WUR): Dolf de Groot, Peter Verburg, Lars Hein, Arend Ligtenberg, Valentina Tassone, David Verhoog, Martha Bakker

Institute of Soil Science and Plant Cultivation Pulawy (IUNG): Tomasz Stuczinsky, Renata Korzeniowska-Puculek, Piotr Koza, Artur Lopotka, Grzegorz Siebielec, Andrzej Zaliwski, Rafal Wawer

Institute of Landscape Ecology, Slovak Academy of Sciences (ILE SAS): Julius Oszlanyi, Zita Izakovicova, Pavol Kenderessy

University Lund (LU): Harald Sverdrup, Hördur Haraldsson

Social Research Unit Forest Research (FR): Jake Morris, David Edwards, Paul Tabbush

National Environmental Research Centre, Lancaster Research Station (NERC): Laurence Jones, Paul Scholefield, Sandrine Petit, Les Firbank

Dept. of Economics and International Development, University of Bath (UBath): Timothy Taylor, Alberto Longo, Ramon Ortiz, Harry Walton

Centre for Environmental Management (UNOTT): Marion Potschin, Marcello di Bonito, Roy Haines-Young
Dept. of Geography and Environment (UNIABDN): John Farrington, Zuzana Drillet, David Watts

Institute of Geological Sciences and Natural Resources Research (IGSNRR), Chinese Academy of Sciences (CAS): Gaodi Xie, Lin Zhen, Yushu Zhang

China Chinese Academy of Social Sciences (CASS), Institute of Sustainable Development: Jiahua Pan, Li Meng, Lou Wei

Brazil Soil National Research Centre of the Brazilian Agricultural Research Corporation (Embrapa Solos): Lucieta Guerreiro Martorano, Margareth Meirelles, Rodrigo Delmonte, Azeneth Schuler, Ana Paula Turetta, Margareth Simões, Joyce Monteiro, Lilian B. E. Veiga, Heitor L. C. Coutinho


Argentina University of Buenos Aires-Agronomy (UBA), Regional Analysis and Remote Sensing Laboratory (LART): Ernesto Vega, Mariano Oyarzabal, Esteban Jobbágy

Uruguay Universidad de la República, Terrestrial Ecology, Ecology Department, Faculty of Science, (UDELAR): Alice Altesor, Santiago Baeza

Responsible scientific officer, DG Research:
Peter de Smedt: 2008-2009
Patrizia Poggi: 2007
Daniel Deybe: 2004-2006

The Steering Committee:
Hubert Wiggering (ZALF)
Reinhard Hüttl (BTUCGFZ)
Arnold Bregt, Peter Smeets (Alterra)

The Peer Group:
David Pannell (University of Western Australia)
Franc Lobnik (University of Ljubljana)
Anne-Yvonne Le Dain (CIRAD)
Peter Nowicki (ECNC)
John Boardman (University of Oxford)
Gertrud Hirsch-Hadorn (ETH Zentrum, HAD)
Ana Maria Yabar Sterling (Instituto de Ciencias Ambientales)
Holm Tiessen (Inter-American Institute for Global Change Research)
Impressum

SENSOR Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions

Project website:
http://www.ip-sensor.eu

Further Reading

Citation:

Report editors:
Katharina Diehl, Bettina König, Katharina Helming (ZALF) and Dirk Wascher (Alterra)

Address for correspondence:
Leibniz Centre for Agricultural Landscape Research (ZALF)
Eberswalder Strasse 84
15374 Muencheberg
Germany
www.zalf.de
sensor@zalf.de

Particular thanks to Matthijs Danes (Alterra) for supplying the map illustrations and to all SENSOR partners who contributed with articles, figures, photographs and advice.

SENSOR was coordinated by Katharina Helming, Karen Tscheming and Bettina König at the Leibniz Centre for Agricultural Landscape Research (ZALF) in cooperation with the module coordinators, Tom Kuhlman and Hans van Meijl (LEI), Marta Perez-Soba and Dirk Wascher (Alterra), Erling Anderson (UCPH), Les Firbank (NERC), Klaus Müller and Stefan Sieber (ZALF), Hanne Bach and Henning Sten Hansen (NERI), Oliver Dilly (BTUC), Paul Tabbush (FR), Lin Zhen (IGSNRR) and Heitor Coutinho (EMPRABA Solos).

Graphic Design:
www.design-meets-science.de
neoplas GmbH

Disclaimer:
This publication has been funded under the EU 6th Framework Programme for Research, Technological Development and Demonstration, Priority 1.1.6.3. Global Change and Ecosystems ([European Commission, DG Research, contract 003874 (GOCE)]. Its content does not represent the official position of the European Commission and is entirely under the responsibility of the authors.

The information in this document is provided as is and no guarantee or warranty is given that the information is fit for any particular purpose. The user thereof uses the information at their own risk and liability.