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(Eds.)

Sustainability Impact Assessment of Land Use Changes

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With 72 Figures, 55 in colour

Springer

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Foreword

There are many reasons why strategic intelligence is required to support policy decisions. These primarily stem from the nature of today's knowledge society with two contrasting trends. On the one hand, there is a trend of increasing human intelligence in the economic, social and political systems. On the other hand, there is a trend towards dissolving certainties about the problems and solutions of today's society. Clearly, more information does not necessary imply more certainties on how to act. What is more, the same facts are often interpreted in markedly different ways: the same policy relevant information can – and often does – results in conflicting framing of a problem by different stakeholders. This is mainly due to competing assumptions, rather then because of inconsistent facts. Therefore, it is not surprising that policy-makers are calling for strategic intelligence to support their understanding of today's challenges, including the relevant aspects of science and technology, their impact and their possible future developments.

Over the last 15 years, Europe has rapidly adopted the practice of developing and using Impact Assessment (IA) tools to support decision-making. Formal procedures and guidance for IA are well established within the European Commission and in most EU Member States. The adoption of IA procedures alone, however, does not guarantee that every policy domain is actually using the full potential of these assessment tools in the preparation of policies and legislation. To substantiate the complex process of IA, the European Commission has launched a series of comprehensive research projects to develop science based sustainability impact assessment tools. The integrated project SENSOR is one of them and I am looking forward to reading and using this publication on the IA concepts and tools developed within the SENSOR project.

Peter De Smedt
Scientific Officer of the SENSOR project.

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Introduction

Land use is a key human activity, which, through the exploitation of natural resources, fosters socio-economic development and alters structures and processes in the environment. At the European level, the Sustainable Development Strategy stresses the need for real integration of economic, environmental and social issues across policy areas. In particular, land use policy aims to promote sustainability pathways of natural resources use and rural development through the decoupling of economic growth from environmental degradation while supporting social cohesion. Manifested with the idea of multifunctional land use, the environment is understood to provide a portfolio of functionalities, which, through proper land use management, can be exploited as environmental goods and services for the benefit of society. A sustainable way of managing land use and exploiting environmental functionalities requires tools that can provide anticipations of possible impacts of land use decisions at all levels of governance.

Impact assessment is an emerging scientific field that includes a variety of tools and methods and that serves various activity and decision making levels. It involves a range of scientific disciplines and methodological approaches. At the European Commission level, sustainability impact assessment is designed to integrate all single sector impact assessment types with the aim of better regulation and fostering sustainable development objectives. To substantiate the complex process of Impact Assessment and develop science based quantitative and qualitative tools, the European Commission launched a series of integrated research projects in its sixth Framework Programme for Research. The Integrated Project SENSOR is one of these. It involves 37 partner organisations in Europe, China and Latin America and develops ex-ante Sustainability Impact Assessment Tools (SIAT) to support decision making on policies related to multifunctional land use in European regions and abroad. SENSOR directly responds to the European sustainability objectives as applied to land use and rural development.

The project is based on three key assessment streams: (1) European-wide, indicator-based driving force and impact analysis of land use policy scenarios; (2) region specific problem, risk and threshold assessment making use of spatial reference systems, land use functions and participatory processes; and (3) case study based, exemplary sensitive area studies in mountains, islands, coastal zones, post-industrialised areas using detailed information on specific sustainability issues, and engaging with stakeholders at local level. Data management systems and institutional analysis complement these assessments.

The impact assessment tools consider policy cases that affect land use in relation to six economic sectors: agriculture; forestry; tourism; nature conservation; transport and energy infrastructure. The list of regional sustainability issues addressed includes spatially explicit environmental functions (abiotic and biotic resources including soil, water, air, biodiversity), societal functions (employment and labour markets, health and recreation, migration, cultural heritage and aesthetic issues) and economic functions (competitiveness, innovation and research).

This book describes results achieved halfway through the SENSOR project. Its focus is on the conceptual design of ex-ante impact assessment tools and on methodological approaches of its components. It is designed as a snap shot of results achieved during the first half of the project and not as a comprehensive representation of all its parts. The design phase for the development of the impact assessment tool was challenging. A logical thread had to be woven that linked global economic trends and policy decisions with land use changes and consecutive impacts on social, economic and environmental characteristics at regional level for Europe. Methods for valuing these impacts and integrating them into the wider sustainability context had to be developed. This was achieved through an integration of top-down quantitative modelling and indicator analysis with bottom-up participatory research. The intention of this book is to provide an overview on the various analytical components and their role in the development of sustainability impact assessment tools for multifunctional land use.

The book consists of 21 peer reviewed chapters organised in five successive parts. They include concepts and approaches to impact assessment, scenarios and modelling, spatial analysis and data issues, indicator analysis, regional and local assessments. Each book chapter describes a specific contribution to the objectives of developing sustainability impact assessment tools. However, each chapter is organised such that it discloses its own scientific value and can be understood independently of the other chapters.

The first part is entitled *Sustainability Impact Assessment*: concept and approaches. It includes five chapters on the impact assessment setting at European Commission level and on how the SENSOR approach responds to this strategy by developing impact assessment tools. The first chapter provides a classification of ex-ante impact assessment procedures at the European Commission level written by Tscherning et al. Similarities and differences in scope, scale and approaches of Sustainability Impact Assessment (SIA), Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) are described. Tabbush et al. outline the potential application of IA in relation to the policy making process for land use. They also discuss the complementary roles of quantitative tools with participatory approaches in the impact assessment procedure. Thiel and König provide an institutional analysis of the use of modelling tools for impact assessment. They describe the conditions, actors and dynamics in the context of the European Commission's Impact Assessment procedures. In this arena, the application of modelling tools is only recently evolving. Tools are only accepted if they are plausible, transparent and built upon official European data. Based on these preconditions the SENSOR approach to ex-ante impact assessment of multifunctional land use had to be constructed. This is outlined in the last two chapters of this first part. Helming et al. provide and overview of the analytical design in SENSOR, in which economic trend and policy scenarios are translated into land use changes at regional scale for Europe. Based on qualitative and quantitative indicator analysis, impacts of simulated land use changes on social, environmental and economic sustainability issues are assessed. The chapter also provides the context of sustainable development and land use multifunctionality, in which the project is placed. Sieber et al., describe the development process and performance of the Sustainability Impact Assessment Toolkit (SIAT), which translates the analytical approach of SENSOR into a meta-modelling system for scenario analysis of land use changes.

The second part of the book is entitled *Scenario modelling of land use changes*. It consists of four papers describing the scenario construction and modelling chain applied in SENSOR. Kuhlman outlines the scenario design on which the prospective studies are built. It consists of global economic trend scenarios and a series of land use related policy cases for a virtual target year of 2025. The approach is to analyse future policy options in the field of land use against a reference based on no policy intervention, in this case reflected by a series of trend scenarios. Jansson et al. describe the modelling framework that was utilised to analyse the economic and policy scenarios in their impact on land use changes. The framework consists of a series of macro-economic, sectoral and land use models that were adapted to each other and to the specific requirements in SENSOR. A linkage of these models allows for a trans-sectoral analysis of the effects of economic changes and/or complex policy scenarios on land use. While in some cases (agriculture, forestry) the framework could build upon well established models, new models or sub-models had to be constructed for other sectors, e.g. tourism and transport. Sick Nielsen and Kaae present a newly developed model on tourism geography for Europe, which provides a geographic disaggregation of tourism loads to regional levels and allows for the analysis of interrelations between tourism attractiveness and regional characteristics. Results of macro-economic and sectoral modelling are integrated in a land use model to display the effects of economic trends and political decision making on land use. Verburg et al. describe this approach of modelling regional scale land use conversions for Europe.

Spatial representation and data issues for European regions is the title of the third part of the book. It consists of three chapters of which the first two deal with the development of regional typologies for land use assessment. Briquel describes the development of European Regional Economic Profiles to reveal regional differences in development trends and sensitivities to policy interventions. The profiles are based on criteria that are of significance in all European regions on the one side, but are sensitive to regional characteristics on the other side. The Regional Economic Profiles served as the socio-economic input into the development of a Spatial Regional Reference Framework (SRRF) for SENSOR, which is described by Renetzeder et al. They combined socio-economic and biophysical characteristics to perform a statistical cluster analysis of the area of Europe. The resulting SRRF consists of 27 cluster regions and provides a flexible tool for impact assessment at regional level. This part concludes with a paper by Hansen et al. describing the GIS based data management system developed for SENSOR. This data management system is a complementary tool to the SIAT.

Four chapters constitute the fourth part of the book entitled *European level indicator assessments*. Frederiksen and Kristensen describe an indicator framework for assessing sustainability impacts of land use changes at regional scale for Europe. Building upon the analysis of the role of indicators in policy relevant studies they establish criteria for indicator selection. Based on this indicator framework Petit et al. address the selection and implementation of environmental indicators for land use changes. Taking two environmental indicators as an example they describe methodological challenges related to the multi-scale and non linear relationships between land use changes and environmental impacts. Compared to environmental analyses, social and economic impacts of land use changes are less well studied and understood. Farrington et al. describe methods for qualitative and quantitative indicator determination and emphasise the difficulties of isolating the direct relationship between land use changes and social and economic parameters from other influencing dynamics. The logical step from indicator analysis towards an integrated assessment of sustainability impacts of land use changes requires an aggregation and comparative weighting of the indicators. A critical review of existing methods for the weighting and aggregation of indicators is provided in the last chapter of this part by Paracchini et al. Criteria for the selection of appropriate approaches in relation to the requirements for impact assessment studies such as in SENSOR are identified.

The last part of this book is entitled *Regional and local evaluation* and consists of five chapters dealing with the regional valuation of land use impacts and the identification of sustainability key issues. Perez-Soba et al describe the conceptual framework of Land Use Functions (LUF) developed for SENSOR to integrate the indicator analyses of social, economic and environmental land use impacts into a regional sustainability assessment. The LUF approach builds upon the concepts of ecosystem services and of agricultural multifunctionality. However, it is adapted to the multi-sectoral uses of cultural landscapes in Europe and considers the social, economic and environmental aspects with equivalent importance. The LUF framework allows decision makers to identify those functions of the land which are affected by land use change scenarios. It facilitates the performance of trade-off decisions between alternative scenarios. Thresholds and targets are often employed in assessment studies for valuation purposes. Based on a literature review, Bertrand et al. discuss the various disciplinary viewpoints on the concepts of thresholds, limits and targets in sociology, economy and ecology. In the following chapter Potschin and Haines-Young describe methods to overcome the limitations of the thresholds/limits concept through the development of so called sustainability choice spaces. They are designed to reveal to decision makers the room for manoeuvre they might have in their decisions. The last two chapters of the fifth part deal with local studies on sustainability issues in specific sensitive regions in Europe. These studies were designed to complement and further substantiate the European wide approach in SENSOR. Morris et al. describe the integration of participatory research into the otherwise model and indicator based analysis of policy impacts in SENSOR. Participatory research is employed to cross check the general assumptions made for the analytical design in SENSOR and to reveal stakeholders perspectives towards sustainability issues related to land use changes. Last but not least, Dilly et al. describe an approach to the spatial classification of sensitive regions in Europe to reveal key sustainability issues in those regions.

This book represents the state of research achieved after the first half of the project. Research is ongoing. At the half-way stage we have established a clear understanding of the potential role of a SIAT, in relation to policies affecting land-use. We have created the tools contributing to the SENSOR SIAT and their crosslinks by defining the steps needed to create such a tool. Indeed, many of these steps have been completed, including the creation of an indicator framework, the SRRF and the LUF approach.

It remains to implement the methodologies designed, evaluate the outcomes, define the sustainability choice spaces, and to integrate all these ideas into the functional SIAT. The tool may require presentation in a number of versions, depending on end-user requirements.

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Part I

Sustainability Impact Assessment: concepts and approaches

Ex-ante Impact Assessments (IA) in the European Commission – an overview

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Abstract

Ex-ante Impact Assessment (IA) was officially introduced into European Commission (EC) policy making in 2002. It is understood as a formal procedure to analyse potential effects of new policies before their adoption. The two main drivers behind this EC initiative are the EU Sustainable Development Strategy and the Better Regulation agenda. IA is carried out on policy level by the Secretariat General of the EC.

In parallel, Environmental Impact Assessments (EIA) and Strategic Environmental Assessments (SEA) exist. They are based at EC Directorate of Environment. EIA analysis impacts of project on the environment and SEA is concerned with impacts of plans and programmes mainly on the environment.

The EU project SENSOR develops ex-ante Sustainability Impact Assessment Tools (SIAT) to support decision making on European land use and environmental policies. The project relates directly to the efforts of the EC, on behalf of the European Union (EU), to integrate all single sector policy assessment into one impact assessment procedure.

This article outlines the historical background of impact assessment and it presents the three IA procedures simultaneously in use by the EC, their level and scope. It aims to provide the reader with a classification helping to identify the role of IA tools as developed in SENSOR for EC decision making.

Keywords
Sustainability Impact Assessment Tools (SIAT), Environmental Impact Assessment (EIA), Strategic Environmental Assessment (SEA), Impact Assessment (IA)

1 Introduction

SENSOR is a research project, funded by the European Commission, and its objective is to develop an ex-ante sustainability IA tools (SIAT) to support decision making on policies related to land use in European regions. Sustainability Impact Assessment (SIA) seeks to identify possible economic, environmental and social effects of proposed policies and their consequences with respect to sustainable development.

SIAT provides political decision makers with land use scenarios which present comprehensive, clear and comparable information on possible consequences, trade-offs and indirect affects of their available courses of action.

There are two main drivers behind the Impact Assessment (IA) procedure of the European Commission. The first is the EU Sustainable Development Strategy (CEC, 2005a); which focuses on the assessment of policy impacts on the economic, social and environmental dimension, including tradeoffs. Secondly, there is the Better Regulation agenda (EU Better Regulation Action Plan (CEC, 2002); which sets out initiatives to promote effective and efficient regulation, and aims to fulfil the Lisbon objectives for a competitive European economy. SENSOR allows for both of these basic EU policy initiatives in the land use policy arena.

The objective of this paper is to provide the reader with an overview on IA procedures carried out at different levels in the EC. The paper outlines historical backgrounds of IA and shows major differences concerning scope, impact and procedure.

2 Sustainability Strategies and Impact Assessment

At the Earth Summit (UN Conference on Environment and Development, UNCED) in Rio de Janeiro in 1992, 178 UN member countries adopted major agreements concerning the change from traditional free market approaches to Sustainable Development. A key role was given to Agenda 21, which includes a comprehensive plan of proposed actions at global, national and local level to achieve these changes. In order to implement § 8 of the Agenda, the "*Integration of environment and development into decision making*", countries are required to develop a National Sustainable Development Strategy (NSDS). Agenda 21 states that NSDS should not result in new strategies but should "*improve and restructure the decision-making process, so that economic as well as social and environmental issues are fully taken into consideration and stakeholder participation is assured*" (§ 8.3). NSDS should be designed to convert mainstream environmental concerns into policy (Brodhag and Taliere, 2006).

By 2006, 40% of UN member countries had developed and and/or partly implemented NSDS (Silveira, 2006). At the most recent 2005 World Summit in New York, 170 states reaffirmed their commitment to Sustainable Development (SD), additionally establishing clear links to the Millennium Development Goals (MDG). It was repeatedly stressed that each country had to take primary responsibility for its own development and that the role of national policies and strategies was of utmost importance for the achievement of SD (Silveira, 2006). This demonstrates that; although the urgent need for NSDS is widely acknowledged; workable procedures for implementing Sustainable Development are still in their infancy. SD as a concept has been kept rather vague. This ensures its transferability to different local and global contexts, as well as to contrasting cultures and regions of the world; however, it also restricts its usefulness as an operational concept, particularly at international level (Cordonier Segger, 2004).

Impact Assessment (IA) is one of the major tools through which the NSDS are implemented (CEC, 2006a). The "Guidance in preparing a NSDS (UN, 2002)", elaborated at the World Summit on Sustainable Development, describes IA as a tool to reveal comprehensive and long-term consequences of policies. The guidance further states that the procedure of IA provides feedback mechanisms whose results cannot easily be ignored by decision makers. The consideration of IA criteria and results, on the contrary, supports concise and tuned decision making processes. The guidance stresses that the participation of local stakeholders in an IA and their interpretation of criteria are key to meaningful IA outcomes.

In general, IA supports decision-making and tries to ensure that potential development options are environmentally and socio-economically sound. IA deals with identifying, predicting and evaluating the foreseeable impacts, both beneficial and adverse, of public and private policy-related development activities. IA is concerned with alternatives and mitigation measures and aims to optimise positive impacts and eliminate or minimise negative ones. It therefore differs from goal oriented impact *evaluation* which assesses the effectiveness of policy options in reaching a defined policy target.

IA needs to be process-oriented, multidisciplinary and interactive. It is increasingly being viewed as an instrument to involve different stakeholder groups (Donelly et al., 1998).

Many different forms of IA exist today which have mainly evolved from the assessment of economic impacts (or of regulations) and the assessment of environmental impacts. However, both strands developed in parallel to other assessments, e.g., gender, social and health. Recent developments endorse the integration of different assessment types into one approach. Abaza (2003) states that the need for integrated, comprehensive approaches towards IA has never been more urgent, considering the growing claims of globalisation and the challenge of unifying sound economic growth, social equity, and environmental protection – while simultaneously alleviating poverty and enhancing trade opportunities.

Integrated assessment and sustainability IAs consider the evaluation of impacts on all three sustainability dimensions - economic, social and environmental - in a systematic, multi-disciplinary approach.

A very recent introduction is Integrated Sustainability Assessment (ISA) which is considered in a number of EU research projects. ISA is based upon the principles of transition management. It is mentioned here for the sake of completeness, but will not be described further.

3 Ex-ante impact assessments at different levels in the European Commission (EC)

In the EC, IA has high priority on the political agenda. Currently, several ex-ante IA procedures are being applied simultaneously, covering different levels and objectives. Three of them are mandatory:

- Environmental Impact Assessment (EIA), a directive to be implemented by EU Member States, coordinated by DG Environment;
- Strategic Environmental Assessment (SEA), a directive to be implemented by EU Member States, coordinated as EIA at DG Environment;
- the EC IA procedure, implemented by the European Commission itself (all Directorates General), coordinated by the Secretariat General.

In Figure 1 the three IA procedures and their different levels and scopes are shown. Further details concerning each procedure are described in the following paragraphs.

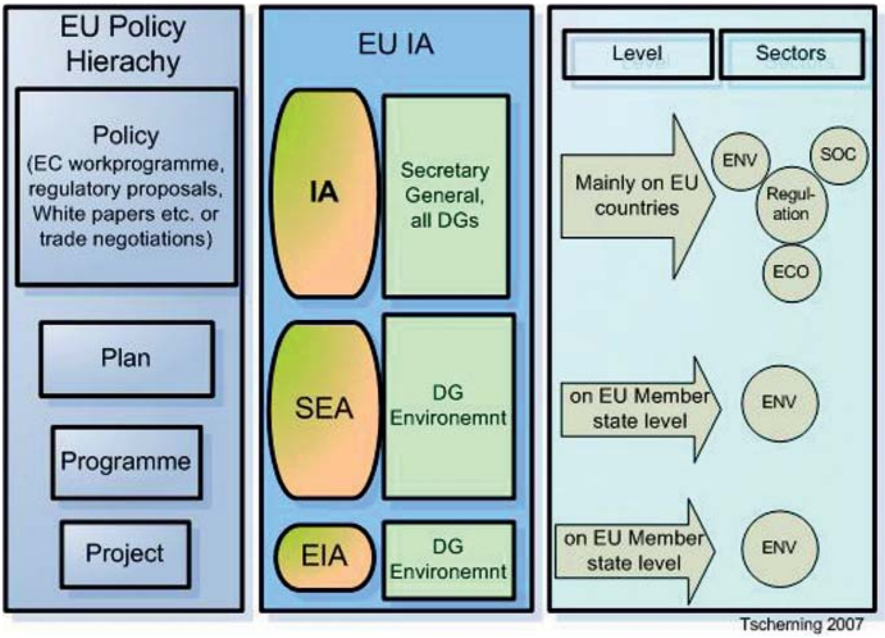

Fig. 1. Classification of EU Assessments (EIA (CEC 1985), SEA (CEC 2001a) and IA (CEC 2005b)) to EU decision-making hierarchy and broad trends in the nature of the different assessments. IA: EU Impact Assessment, EIA: Environmental Impact Assessment, SEA: Strategic Environmental Assessment, ENV: Environmental Sector, SOC: Social Sector, ECO: Economic Sector, DG: Directorate General

3.1 Environmental Impact Assessment (EIA)

Background

Environmental Impact Assessment (EIA) was enacted in the first National Environmental Protection Act (NEPA) of the United States in 1969 (Modak and Biswas, 1999). Today NEPA is considered as the cradle of all IAs: it provided the legislative background and formulated essential components of EIA. One of NEPA's main purposes was to facilitate the use of science for decision making. The procedure of EIA requires the identification of potential alternatives to any specific proposal, the analysis of impacts, and a justification of why the preferred action was chosen (Pope, 2007). EIA was meant to be applied ex-ante to all actions with a potential effect on the environment, extending from project proposals to policy appraisals. EIA spread rapidly to other countries, e.g., Canada (1973), Australia (1974), former West Germany (1975) and France (1976) (Therivel et al 1992). Today it has been established in more than 100 countries at different institutional levels as an important decision support tool (Donelly et al., 1998).

The EIA Directive

EIA was first introduced into EU legislation in 1985 (CEC 1985) to identify and assess the effects and consequences of public and private projects (see box 1) on the environment before authorisation is given. It was amended in 1997 (CEC, 1997) and had to be converted into EU Member States directives by March 1999 (CEC, 1985). The participation of public opinion was possible in respect of certain projects. In 2003 it was assured through the Aarhus convention (CEC, 2003). The EIA Directive covers a broad range of activities ranging from industrial to infrastructure projects. A list of respective projects is given in Annex II and III of the Directive.

Article 2 of the directive requires that „*Member States shall adopt all measures necessary to ensure that, before consent is given, projects likely to have significant effects on the environment by virtue inter alia, of their nature, size or location are made subject to an assessment with regard to their effects.*" Furthermore, the directive demands that the results achieved in the EIA „*must be taken into account in the development consent procedure*."

These main requirements are further elaborated in the directive, and in the different EIA systems existing in the Member States. Although procedures adopted may vary, the stages are generally similar.

The EIA procedure

Screening is the first stage in which a "competent authority[1]" decides whether or not an EIA is required for a particular project. The requirements for screening are described in Article 4 of Directive 97/11/EC. EIA is mandatory for some projects and is based on individual Member State decisions for other projects. Screening results must be made public. The following stage, called *Scoping,* is mandatory only in some Member States. The Directive proposes that the project proponent may require a scoping opinion by the "competent authority". At this stage the authority

[1] A competent authority is one designated by the Member State as responsible for performing the duties arising from the EIA directive

identifies which matters have to be covered in the "environmental information". Referring to the required information, the project proponent has to carry out environmental studies which will be delivered to the "competent authority", together with an application for development consent (*Submission of Environmental Information to Competent Authority*). In a large number of Member States the environmental information is presented in an Environmental Impact Statement. The collected environmental information must be presented to authorities with environmental responsibilities and to other interested organisations as well as to the public. This stage is called *Consultation with Statutory Environmental Authorities, other interested parties and the public*. It is followed by the *Consideration of the Environmental Information by the Competent Authority* in which the authority must reach a decision which is finally announced and made public (*Announcement of the Decision*). Measures to mitigate potential adverse environmental effects need to be described. For Natura 2000 sites special EIA rules apply.

Guidelines on scoping, screening and the environmental statement review are published by the Commission, and provide authorities, developers, consultants, researchers, organisations and the public with relevant information and checklists.

EIA scope

EIA is associated with decisions relating to projects. Usually, decisions concerning the location and the design of a project are taken before the construction work starts. Instead of prevention strategies, mitigation measures are often adopted. Later in the process, feasible alternatives to the project intervention are often limited to a minimum (BEACON, 2005). EIA outputs are detailed and the key data sources used are often from field work or sample analysis. Data tend to be qualitative and assessment benchmarks are often legal restrictions and best practices (BEACON, 2005).

EIA is defined by its reactivity because it applies after the developer or proponent has already finished the proposal (Pope et al 2004). The developer or proponent of the project itself is responsible for carrying out the requested environmental studies identified in the scoping process by the corresponding authorities (Sheate et al., 2001). In conclusion, EIA is a proponent driven, reactive approach (Pope et al., 2004).

3.2 Strategic Environmental Assessment (SEA)

Background

SEA aims at integrating environmental concerns into strategic decision making. Thereby, public and environmental authorities are fully involved in the planning process. SEA evolved in parallel with EIA and was initially carried out when the scope of EIA seemed too narrow for the assessment of a given proposal. This could be in terms of allowing for sound, sustainable, and global decision making (Partidário, 1996), or in regional or landscape level assessments, where the spatial requirements went beyond the EIA approach. Recently, it was argued that SEA has the capacity to support the development of policy and planning practices stressing the environmental component. SEA may therefore play a fundamental role in promoting sustainable principles and practices, since it considers cumulative and side effects (Eggenberger and Partidário, 2000).

In an international context the term SEA refers to a formalised procedure assessing the impacts of policies, programmes and plans. While SEA practises within EU countries is formalised by the EU SEA directive (CEC, 2001), no international standard has yet been established. Currently many existing SEA procedures are closely related to or based on EIA and the EC SEA directive. Similar policy tools and strategic approaches, widely present in developing countries, diverge from the European formal definitions of SEA but integrate parts of their characteristics and elements. For the further development and international standardisation of SEA all existing approaches should be considered equally (Dalal-Clayton and Sadler, 2004).

The SEA Directive

The EC elaborated the SEA directive "*to help to reach the goal of sustainable development*" (CEC, 2001a). It was adopted in 2001 and required Member States to implement SEA by 2003. SEA ensures that the environmental consequences of plans and programmes (see box 1) are identified and assessed before their implementation. For some of these, described in the directive, SEA is mandatory, whereas in other cases Member States have to make the decision case by case. Public and environmental authorities are fully integrated in the planning phase to improve transparency within the decision making process.

The objective of the SEA Directive as described in Article 1 is: „*to provide for a high level of protection of the environment and to contribute to* *the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development".*

The SEA procedure

SEA follows a similar procedure to EIA. After a *Screening* phase, investigating the necessity of a SEA, the S*coping* phase determines which issues need to be addressed in the assessment, and by what means. During the third phase of the procedure, called *Environmental Assessment,* impacts and their significance are examined. Furthermore, alternatives to the proposed measure are stated and discussed. Findings of the *Environmental Assessment* are published in a report. The Environmental Report is a key feature of SEA. The Directive describes in detail which information has to be included. In the next stage of the assessment, the report is *reviewed* by environmental and other authorities and by the public. After this stage the decision maker approves or refuses the plan or programme, making reference to the SEA. Proposed *implementation and monitoring* methods are discussed and evaluated. *Consultation and stakeholder participation* is critical to the success of SEA and is carried out in tandem with the procedure from the early stages onward.

SEA scope

In contrast to EIA, which is initiated in response to a proposed plan, SEA serves as a support tool for decision-makers. SEA considers wider ranges of impacts and looks for alternatives to the proposed measure. It is a proactive tool and accompanies the planning of the proposed measure itself, allowing for the development of sustainable solutions.

The United Nations Economic Commission for Europe (UNECE) considers SEA as a key tool for Sustainable Development, because it is undertaken earlier in the decision making process than EIA. The SEA protocol was adopted by the ESPOO Convention paying special attention to transboundary contexts (UNECE, 2007). Hence, being advocated by strong organisations, SEA will most probably gain wider importance in the near future.

A detailed review of the relationship between EU EIA and EU SEA Directives is given in (Sheate et al., 2005).

Box 1: A proposed definition of policy, plan and programme in an IA context

Proposed definitions for Policies, Plans and Programs

According to Wood (1991), a ***policy*** *can be defined as an inspiration and guidance rationalising the course of action of a government …A* ***plan*** *can be defined as a set of linked proposed actions – with a time frame – to implement the policy ….Finally a* ***programme*** *can be defined as a set of* ***projects*** *that specify the geographical and temporal design criteria of the plan objectives.*

The example "High Speed Rail" ***Policy****: Development of a High Speed Rail network to promote the shift of passenger traffic from air to rail*
Plan: *Where and when to implement the High Speed Rail?*
Program: *Concrete proposal to build a High Speed Rail track between city A and city B.*
from BEACON Manual (2005)

3.3 EC Impact Assessment (IA)

Rationales – Sustainable Development and Better Regulation

Research in IA originated only a few years ago, in Canada, the UK and the EU (Buselich, 2004). So far the challenge of adapting existing environmental assessment, or regulatory approaches, to the requirements of Sustainable Development in its full complexity has not been carried out. Nor have newly developed approaches succeeded in fully integrating social, economic and environmental impacts and their interrelations at any level. Furthermore, the large number of different approaches and the alphabet soup of acronyms make for a confusing picture (Dalal-Clayton and Sadler, 2004).

The established understanding of IA as a purely regulatory instrument (Regulatory Impact Assessment, RIA) for cost-benefit analysis has changed in many countries over the last decade. There is a worldwide trend to integrate environmental, economic and social issues into one IA procedure. Even so, IA may still only enable policy makers to choose the policy option with the greatest benefit at the lowest cost. It remains questionable whether a balance can be achieved between the two core aims of Sustainable Development and Better Regulation. A background of disparate issues, actors and institutions in IA hampers the process (Jacob et al., 2006).

In the Amsterdam Treaty of 2002, the EU committed itself to "*the achievement of a balanced and sustainable development*" (CEC, 2002). The EU Strategy for Sustainable Development proposed by the European Commission (EC) (CEC, 2001b) was adopted by the European Council in Goteborg in June 2001. The 2001 strategy postulated the need "*to judge how policies contribute to sustainable development*". Additionally, the full effects of a policy proposal need to be carefully assessed; including estimates of its economic, environmental and social impacts inside and outside the EU. In 1999, Sustainability Impact Assessment (SIA) had already been adopted by DG Trade in anticipation of the World Trade Organisation (WTO) round of negotiations. In the context of WTO, Sustainability Impact Assessment seeks to identify possible economic, environmental and social effects of trade agreement outside the EU. The EC pledged itself further to develop methodologies for Sustainable Impact Assessment (CEC 2006b), by contracting consultants who developed a methodology and carried out preliminary assessments on the WTO round.

The EU strategy for Sustainable Development was revised in December 2005 (CEC, 2005a) and further renewed. The actual EU Sustainable Development Strategy (CEC, 2006a) was adopted by the European Council in June 2006, and explicitly reinforces the importance of high quality IA as a tool for better policy making. It stated that all EU institutions should ensure that major policy decisions are based on proposals which have undergone an IA, and equal consideration should be given to the social, environmental and economic dimensions of sustainable development. The document additionally strengthens the importance of collaboration with partners outside the EU, to meet the long standing commitment to global sustainable development (CEC, 2006a).

In the EC context "Better Regulation" means simplifying, improving and streamlining the EC regulatory environment. Better Regulation is a key to "*making Europe the most competitive knowledge-based society of the world by 2010*" laid out in the EU's Lisbon strategy from 2002. EU Better Regulation initiatives started in 1992, although results have been limited due to the complexity of the task and the lack of policy support. In a further attempt to lobby for Better Regulation, the EU Action Plan: "*Simplifying and improving the regulatory environment*" (CEC, 2002a) was elaborated. It states "*By the end of 2002, the Commission will implement a consolidated and proportionate instrument for assessing the impact of its legislative and policy initiatives, covering regulatory impact assessment and sustainable development (in the economic, social and environmental fields) and incorporating the existing instruments and methods"*. In "Impact Assessment: next steps", the 2004 progress report, the EU IA framework is presented as an integrated approach supporting competitiveness and Sustainable Development. Both papers explicitly mention the merging of Better Regulation and Sustainable Development into one common assessment approach.

The two main drivers behind the IA procedure of the European Commission are the EU Sustainable Development Strategy and the Better Regulation agenda. The first focuses on the assessment of policy impacts on the economic, social and environmental dimension, including tradeoffs, and the second promotes effective and efficient regulation, aiming to fulfil the Lisbon objectives for a competitive European economy (Franz and Kirkpatrick 2006).

The IA EC Communication

In response to its Goteborg commitment to implement Sustainable Development, and to its commitments at the Laeken council (EU Better Regulation Action Plan (CEC, 2002a) to implement better regulation principles (Tamborra, 2003) the EC systematically started the development of an integrated, centralised IA framework.

These efforts resulted in the Commission's Communication on IA which introduced an internal process of IA for major proposals in all policy areas, including trade (CEC, 2002b). One main objective of the EU's IA is to improve the quality of proposals. It applies to all major Commission proposals which are listed in the Annual Policy Strategy or in the Work Plan. In this final document the EC does not promote Sustainability IA *per se* but stresses the need to develop an Integrated IA process; streamlining, substituting and integrating all the existing, separate IA measures, including sustainability IA. The Commission published internal guidelines in 2002 ("Impact Assessment in the Commission - Guidelines" and the "Handbook for Impact Assessment in the Commission - How to do an Impact Assessment") on necessary procedures when carrying out an IA. On 15 June 2005 new guidelines were published (CEC, 2005b), replacing the Guidelines and the Handbook. These were further amended in 2006, and they describe the IA procedure and the six analytical steps of the IA itself in detail.

The IA procedure

IAs are conducted by the responsible DG (Directorate General) within the European Commission. The Secretariat General recommends three steps/phases during the EU IA procedure. Firstly, the IA needs to be integrated into the Strategic Planning and Programming Cycle of the Commission. This means that the IA of each initiative has to be described in a Roadmap and is part of the Annual Work Programme of the Commission. The roadmap shows detailed information about the IA procedure. Additionally, an Inter-Service Steering Group (ISG) needs to be set up. The ISG is compulsory for cross-cutting items and always includes the Commissions Impact Assessment Unit (SG.C.1). These units, made up of different departments of the Commission, are meant to broaden the perspective of the assessment. Subsequently, all interested parties must be consulted, and expertise needs to be gathered, before the IA can be carried out. This latter part of the assessment is also known as stakeholder consultation. Minimum standards for consultation are set out in (CEC, 2002c).

Secondly, findings of the IA need to be presented in an assessment report, even if the policy initiative itself is withdrawn. Assessment reports should summarise the work undertaken for the IA and state assumptions and uncertainties. The report should be written in a simple non-technical language and technical details, or supporting documents, should be included in an annex. Thirdly, the report - together with the policy proposal - is disseminated for information to other institutions and summarised in a press release. Finally, the report is published on the Europe website by the Secretariat General (CEC, 2008).

The assessment itself is divided into six analytical steps which are described in Tabbush et al (2008).

In 2006, the EC established an IA Board, under supervision of the Commission's president, comprising six officers from different EC departments who had expertise in IA and policy support. The mandate of the board is to evaluate individual proposals and guide initiatives throughout the political decision-making in the EC.

By June 2007, the Commission had carried out 230 IAs and had gained considerable experience in the area. In spring 2007 the assessment procedure was further tested; with the help of an external evaluation, initiated by the European Council. The outcome is the "Strategic review of Better Regulation" which will be presented in spring 2008. Subsequently, the Commission will gradually introduce changes into the existing system. Among other things, these changes concern methodologies and data availability/quality across the three pillars, stakeholder consultations and Inter-Institutional aspects in Member States (Day, 2007).

IA scope

The goal of the EU IA is to estimate the environmental, economic and social impacts of a proposed policy in order to provide political decision makers with comprehensive and clear information of possible consequences, trade-offs and other implications. The EU IA assists decision makers, but is not a substitute for political judgment. It may include an e-valuation of the proposal (Will policy objectives be reached?) but mainly concentrates on the assessment of possible unforeseen impacts in different sectors, trade-offs and ramifications of a given policy intervention. The new assessment system replaces all single sector assessments; e.g., business, gender, trade, and environmental/ regulatory. It is intended to overcome the shortcomings inherent to single sector assessment (Lee and Kirkpatrick, 2004).

The new IA guidelines cover the Commission's work programme (regulatory proposals, white papers, expenditure programmes and negotiation guidelines for international agreements).

Although these guidelines still commit the EU IA to the ex-ante analyses of the impacts of policy proposals on the three sustainability dimensions, the assessment system is termed IA (Bartolomeo et al., 2004). The focus on the integration of Sustainable Development into EU policy has gradually declined. The EC still officially claims to assess potential economic, social and environmental impacts of policy options, but reduction of costs is becoming increasingly important in regulative issues. Critics already fear that established social and environmental standards will be undermined by Better Regulation (Paul, 2007).

4 Conclusion

Three different types of IA exist in parallel at the European Commission: Environmental Impact Assessment (EIA) which was first introduced into EU legislation in 1985 identifies and assesses environmental effects of projects. It is based at DG Environment and carried out at Member State level. Strategic Environmental Assessment (SEA) was adopted 2001 to make sure that environmental consequences of plans and programmes are assessed before the implementation of such. SEA is also carried out on Member State level and is based at DG Environment. Impact Assessments (IA) are conducted on policy level and are carried out by the different DGs in the EC. The procedure was introduced in 2002 to show potential effects of policies before their adoption.

Impact assessment is implemented at EC level and is meant to integrate all single assessments into one comprehensive system for European policy making. SENSOR's sustainability IA tools respond to this approach and concentrates on land use and environmental related policies. SENSOR is region-based and makes potential impacts on EU member state level

(NUT3) visible. It integrates the social, economic, and environmental dimension as well as regulation issues. The SIAT developed by the SENSOR project, supports decision makers in the EC to perform concise and reliable IAs.

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Impact Assessment in the European Commission in relation to Multifunctional Land Use

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Abstract

This chapter reviews the potential application of Impact Assessment (IA) in the European Commission in relation to issues of land use. Drawing on qualitative research conducted with EC policy-makers, conclusions are drawn concerning the probable role and application of SENSOR's Sustainability Impact Assessment Tool (SIAT) in the course of the EC Impact Assessment procedure.

A participatory approach is integral to the IA process, with national level stakeholders consulted throughout at EC level. In the current procedures, opportunities for consultation within the short time span of an IA tend only to reach lobby groups and activists, and citizens who are affected by the policy are unlikely to contribute directly as individuals to the debate. There are opportunities to engage local stakeholders as part of the operation of the tools themselves, but this is likely to be restricted to medium-term strategic development of the tools, as the time required may be outside the timescale normal for operational IA.

Although some IAs have been carried out to a short timescale and have consequently been brief and descriptive, there is evidence of an increasing importance being given to IAs during the policy-making process, and it is concluded that flexible tools are needed that can exist in different forms:
1. a superficial level which doesn't require reprogramming and works for a wide range of policies and could be used immediately by trained desk officers. 2. an intermediate level which requires several weeks' work to pro-

gramme and run the tool for a particular policy area 3. a strategic level where the tool is being developed and programmed for one or more policy areas and used over successive years to contribute at particular points in the development of specific policies. This third level of complexity to include updating and reprogramming the source models might be necessary to deal with a completely new policy area, or one that has not yet been modelled adequately, and this would require a longer term expert study.

Keywords

Sustainability, Impact Assessment, ex ante, policy appraisal, EC

1 Introduction

Tscherning et al. (2008) have described the evolution of the Impact Assessment (IA) process in Europe, culminating in the publication of the EC "Guidelines for Impact Assessment" (CEC, 2005). The sixth framework programme of research for the European Commission called for work to support this process, and the Integrated Project SENSOR is one of a suite of projects working on IA in various contexts. In the case of SENSOR, the context is land use, and the impacts of European policies, as integrated across social, economic and environmental dimensions. The project aims to produce Sustainability Impact Assessment Tools (SIAT) that predict impacts of land-use policies, or policies that affect land-use, in relation to sustainability issues across six sectors: Agriculture, Forestry, Transport, Energy, Nature Conservation and Tourism. This chapter establishes the frame of reference for the development of SIAT, drawing on information from interviews and workshops at EC level.

1.1 Land use

"Land use" can be conceived of in a number of ways. In one sense, it is simply a categorisation based on the allocation of different types of economic production system to different parcels of land. On the other hand, the notion of "multifunctional landscape" is a more complex interpretation. In its narrow sense, the term "multifunctional" has been applied in agriculture to include functions other than the production of food (or other materials) to the market economy. Other "joint", "spill-over" or "external" benefits are recognised by economists, such as open space, wildlife habitat, biodiversity, and viable rural communities. The multifunctional nature of agriculture has been used as an argument for continued economic support for production, while counter arguments are that this distorts the international market for goods, often to the detriment of poorer nations, and that there are other ways of promoting the delivery of these externalities (Bohman et al., 1999). When the landscape is considered, rather than a single economic sector, it is seen to support a range of economic activities (Helming et al., 2008). As described in the Millennium Ecosystem Assessment (MEA, 2005) landscape provides a whole range of ecosystem services, supporting several types of economic activity while contributing to human well-being, sometimes in ways that are external to the market economy. In this sense landscapes can be regarded as multifunctional. Landscape is seen as a source of support for all areas of human need (European Landscape Convention, 2000) and this gives rise to the idea of landscape (and its embedded land-use) as "multifunctional". According to Ling et al. (2007): "Multifunctionality is not simply an amalgam of adjacent different land uses – that is, a mixed-use development: rather, by working with the landscape, it should encourage different functions to operate within it in an integrated way." Such a holistic view, stressing integration between functions, is consonant with a post-Rio notion of Sustainable Development (SD), to include socio-cultural, environmental and economic dimensions. The aim of SIAT is to predict the effects of projects or policies on land use functions, in relation to issues of sustainability.

1.2 Sustainability Assessment

Sustainability Assessment (SA) is the general term for a methodology of which the IA procedure of the EU is a specific example. Tools for sustainability assessment have been classified according to their "temporal focus" (whether they look backward; *ex post*, or forward; *ex ante*) their "object of focus" (e.g. products, projects or policies) and the extent to which they integrate the assessment – "the extent to which the tool fuses environmental, social and/or economic aspects" (Ness et al., 2007). In this classification the tools produced by SENSOR will be for the *ex ante* assessment of EU level policies, specifically those policies that are likely to result in changes of land use. The extent of integration requires some further consideration. Integration may also be interpreted to include a number of different analyses and assessments aiming to establish a link between drivers and impacts or dimensions of a problem (Scrase and Sheate, 2003). Implicit in most SAs are at least two types of integration:

- integration of sustainability considerations into policy development and decision making, and
- integration between dimensions of development (social, environmental and economic), i.e. assessment of interlinkages,

but other aspects of integration may also be central, such as

- integration of policy objectives, i.e. enhancing policy coherence
- integration of stakeholder interests including far-away stakeholders, and
- integration over time.

Pope et al. (2004) discuss sustainability (impact) assessment tracing its origins in the experiences with environmental impact assessment (EIA) and strategic environmental assessment (SEA). They differentiate between two types of SA, which they name EIA-driven integrated assessment and objectives-led integrated assessment. The first type enters the decision-making process at a stage where most decisions have been taken and possibilities of avoiding or mitigating adverse impacts are in focus. Impacts are usually assessed against a baseline, and the exact position of a sustainable state for that particular proposal is unknown. This approach reflects a Triple Bottom Line (TBL) model that aggregates indicator values against the three pillars of sustainability (Economy, Society, Environment) separately. An additional aim in this approach may be to integrate the impacts over the three dimensions.

The second type is an *ex-ante* process, where the impacts of a proposal are assessed against an outcome defined by specific environmental, social and economic objectives – preferably objectives integrated between the dimensions. It is thus differentiated from the first by entering the decision-making process in an earlier stage, but also by assessing outcomes against policy objectives. Crucial questions for SA are thus if these objectives can lead to improved sustainability, and from the point of view of which section of society.

The two approaches are summarised in two questions:

a) Are the TBL impacts acceptable? (trend oriented) and
b) Does this proposal make a positive contribution to (integrated) TBL goals? (goal oriented).

The central issue in the latter approach is how to define sustainability goals. Wiek and Binder (2005) approach this aspect by discussing solution spaces for decision making; elsewhere the framing of sustainability goals have been considered in the context of constraints that define the "room-for manoeuvre" in policy design. This work seeks to identify thresholds, based on knowledge of system, normative targets, and identification of conflicts among sustainability ranges (Potschin and Haines-Young, 2008). Specific targets for the indicators are here defined by principles of Sustainable Development rather than reference to a former state or to another system (bench-marking). Coherent policy objectives are essential for such impact assessments to make sense. Thus Pope et al. (2004) argue that in the objective-led procedure not only impacts need to be integrated - but also policy objectives themselves.

Based on an account of the historical development of the concept of Sustainable Development from a former consideration emphasising ecological sustainability, de Ridder (2005) makes a distinction between Integrated Assessments and Sustainability Assessment. Sustainability Assessments need as a minimum to consider not only environmental, social and economic issues and their interactions, but additionally three cross-cutting aspects derived from principles of environmental stewardship, global equity concerns and the needs of future generations.

Several sources of EC sustainability principles and criteria exist. Obvious sources are policy documents, of which the Sustainable Development Strategy (CEC, 2001) is central, and the related Sustainable Development Indicator set developed by Eurostat. Together, these would be a source for an objective-led strategy for impact assessment, as they address key policy objectives for Sustainable Development (SD) as defined by the EC. The SD indicators moreover include other issues like production and consumption patterns as well as good governance resulting from the World Summit on Sustainable Development in Johannesburg in 2002 and economic competition as emphasised in the Lisbon Strategy (CEC, 2002a).

According to Owens et al. (2004), Sustainability Impact *Appraisal* would be the term that best describes the aspirations of SENSOR. These authors define “appraisal”, “to include a variety of *ex-ante* techniques and procedures that seek to predict or evaluate the consequences of certain human actions”. The distinction between *ex-ante* appraisal, continuous monitoring, and *ex-post* evaluation is important. Indicators chosen for monitoring are often non-specific, simply referring to how the system is changing in response to often unknown or unforeseen events. *Ex-ante* appraisal, on the other hand, considers the impacts of policy options, and follows some pre-determined value system or “normative presuppositions” (Owens et al., 2004). For instance, the ideas that a sustainability appraisal should protect the interests of future generations, and should achieve an equal balance between economic, social and environmental issues represent such presuppositions.

The notion that “equal weights” should be given to the three dimensions of sustainability, derives from the shift from assessments focused on the environment (EIA), and the apprehension that in doing so, social and economic considerations might come to dominate and lead to environmental damage. Arbter (2003), for instance stated that: “SIA will only be effective in promoting long-term and high quality strategies, if environmental issues are not overshadowed by economic and social considerations. The key success factor is to keep SIA equal weighted.”

A similar point was made by an official from the EC Secretariat General interviewed in August 2005: “the idea is you would present the evidence of the impacts across all three dimensions without giving weight to one over the other, but then at the political level that’s when they decide whether the positive environmental impacts are such that it’s worth paying the sort of financial costs; that’s for a political decision maker to make that choice its not for the impact assessment”.

In practice, it is hard to think of any single indicator from any one of the three pillars of sustainability, that has no salience with the other two. For example, water quality is an environmental indicator, but perception of acceptable water quality also varies with economic prosperity and water quality is also a determinant of social well-being. There is therefore a need for a balanced integration of assessments based on pre-determined thresholds and norms. Arbter (2003) goes on to suggest that such a balance can be achieved by:

- Pro-active participation of the interest groups concerned,
- Transparency within the whole process,
- Justification of trade-offs and
- Up-grading of monitoring

Current Practice in the European Commission

Impact assessments related to the Commission’s work programme have embraced an impact assessment procedure, which aims to balance the three sustainability domains (economic, environmental and social), and a guideline and handbook for impact assessment was published with this approach (CEC, 2002b, 2003). The procedure was revised in 2005 and the impact list refocused following the Commission’s call for greater attention to impacts on competition (CEC, 2004). This resulted in renewed guidelines (CEC, 2005), and while the former handbook explicitly spoke about Sustainability Assessment and criteria for this, the new guidelines make no reference to sustainability, although the screening list of impacts covers the three dimensions.

It has been argued that there has been a general move away from addressing Sustainable Development as a substantial issue defining ultimate aspirations, towards a focus on procedural aspects, defining a pathway to

change (ECSG, 2004). As a result, SD is mainly considered to be an exercise in balancing and integrating its three dimensions (economic, social and environmental), rather than focusing on environmental protection and development. According to this study, which advocates a Triple Bottom Line (TBL) approach, appraisal focuses on Sustainable Development policy issues, which by definition are dynamic and may be interchanged with others as priorities change. An essential aspect of this is that rational methodologies for balancing trade-offs among dimensions seldom exist, and consequently this becomes a political process, left to decision-makers, with or without the aid of some form of participatory process. Thus balancing future generations needs against the present, as well as environmental objectives against economic, results from the specific policy process. The present emphasis on the development of sustainability assessment tools reflects this change. The development of these tools has followed a trend away from specific sustainability criteria to a general TBL assessment.
The Handbook identified the following principles for sustainability:

- maintaining a certain level of stocks of resources (natural, human, social and man-made);
- efficiency in resource use for production of “well-being”; and
- equity (distribution of resources).

Based on these normative issues, three sustainability criteria were identified:

- Protection and renewal of stocks of resources;
- Technical efficiency with which resources are used to produce goods and services; and
- Equity within and between generations.

The key questions to identify SD are drawn from these criteria were then:

- Does the proposal have an impact on stocks (maintenance, renewal or destruction)?
- Does the proposal improve or reduce the technical efficiency with which resources are used to produce well being (for example goods and services for consumption)? How does it affect innovation or productivity? How does it affect “institutional efficiency”?
- What are the distributional impacts of the proposal? Are existing inequalities preserved, reduced or accentuated?

While these questions did not specify any predefined sustainability targets, they addressed certain normative sustainability criteria as discussed above. The recently released Guidelines (CEC, 2005) do not refer to these criteria at all, but adopt, with a few revisions, the impact issues addressed in the first version of the handbook. Thus the Guidelines have moved away from substantial definitions of Sustainable Development, while keeping the focus on a balanced approach to the three dimensions of sustainability.

2 Impact Assessment Tools in SENSOR

The framework for the production of Sustainability Impact Assessment Tools (SIAT) in SENSOR is closely based on the approach to impact assessment in the EC and the issues and questions developed in this. This approach is summarised below:

The revised method is two-stage: The preliminary assessment is now replaced by a ‘Roadmap’, followed by a second stage impact assessment, if deemed necessary in the first stage. The Guidelines (CEC, 2005) describe the following key questions to be answered in relation to a policy initiative:

- What is the nature, magnitude and evolution of the problem?
- What should be the objectives pursued by the Union?
- What are the main policy options for reaching these objectives?
- What are the likely economic, social and environmental impacts of those options?
- What are the advantages and disadvantages of the main options?
- How could future monitoring and evaluation be organised?

The method developed and documented in the guidelines draws on recent work to define evaluation methods; the programme flow and identification of impacts have been inspired by the methodologies for evaluation used in the Commission, such as the evaluation of the expenditure programme.

According to the Guidelines, the IA process proceeds in six steps (Fig 1). Most analytical attention is concentrated on Step 4; the first three steps will be the direct responsibility of the policy makers. However, stakeholders (especially including member states) may be consulted by the EC at every stage, and “general principles for consultation of interested parties” have been published (CEC, 2002c). The tools themselves may also be participatory and include stakeholder engagement.

A comprehensive checklist of impacts is given in the Guidelines, under each of the triple bottom line (TBL) headings (social, economic, environmental). The process is innovative, in that it avoids listing purely quantifiable indicators, instead asking a series of more-or-less open questions about the social, economic and environmental impacts that the policy option under test might have. The challenge, then, is to devise tools and methods that help policy makers to find answers to those questions, in particular contexts.

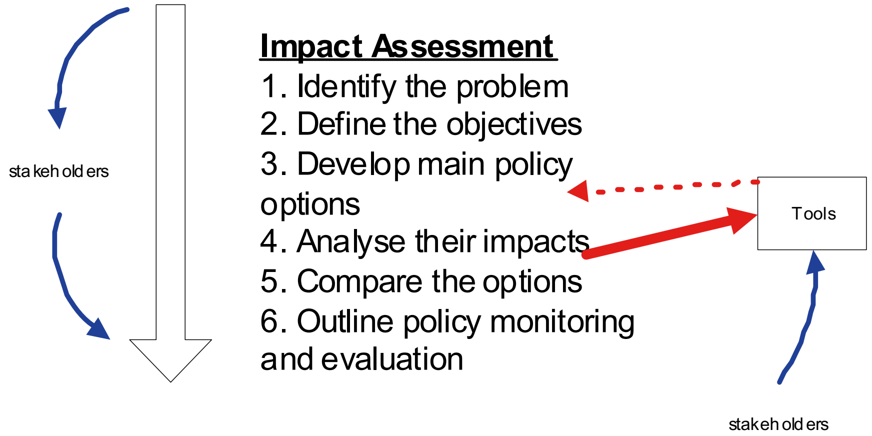

Fig. 1. Impact Appraisal in the EC (adapted from the EC Impact Assessment Guidelines (CEC, 2005), to show the opportunities for stakeholder involvement, and the stage in the process where IA tools are most likely to be applied (solid red arrow; stages 4 and possibly 5). The dotted red line indicates a possible feed-back loop, helping policy makers to refine the options. Stakeholders (left) may be involved throughout the process, especially at the level of member states. Processes for engaging local stakeholders can be included as part of the tools themselves (right).

3 End user research

Participatory research with potential end users of SIAT, using qualitative social science methods, was carried out as part of SENSOR, and this set out to answer questions related to the institutional status of IA and the need for IA tools as expressed by EC officials. The conclusions below are based on nine individual semi-structured interviews with EC officials, and a series of workshops and meetings. The interviews were recorded and transcribed for analysis along with notes and reports from the workshops and meetings. Of particular significance were a workshop at the Joint Research Centre (JRC) in ISPRA, Italy in June 2005, and a meeting with DG TREN in Brussels in March 2006. Results from further interviews, concerned specifically with institutional analysis are presented in Thiel and König (2008).

The Secretariat-General (SG) has been responsible for developing and promoting the new IA system within the Commission, including the production of guidelines and handbooks. Different units have been involved at different times, in particular: SG H2 (Institutional Matters and Better Regulation), SG C1 (Strategic Planning and Coordination/Programming), SG D1 (Task Force, Lisbon Strategy). Impact assessments are conducted by a lead DG, which is chosen because it has a major stake in the initiative to be assessed. Inter-Service Steering Groups, often with representatives of several DGs, are set up to oversee the process for proposals that cut across the interests of more than one DG. There are also units within many DGs (for example Environment) which are responsible for assessment and evaluation for initiatives within their particular sectors and these units may participate in integrated impact assessments on behalf of their DGs. In principle, Impact Assessment and the policymaking process within the EU Commission now overlap considerably, since the definition and scope of IA has been stated to include all six steps from identifying the problem through to evaluation of the policy (CEC, 2005). The forthcoming policies that will require IAs are to be found in three key documents, which are published annually as part of the strategic programming cycle: the Annual Policy Strategy, Work Programme and Roadmaps; examples current at the time of writing are given below:

- The **Annual Policy Strategy** 2008 was published on 21 February 2007. It establishes the policy priorities for 2008, identifies the initiatives that will help to realise them, and the budgetary framework that is being adopted.
  See: http://ec.europa.eu/atwork/synthesis/index_en.htm
  (Accessed November 2007).
- The **Work Programme** provides considerably more detail of use in the selection of potential policy cases. It translates the Annual Policy Strategy into policy objectives and an operational programme of decisions to be adopted by the Commission. The Work Programme for 2008 was published on 23 October 2007.
- A preliminary Impact Assessment will already have been conducted during the preparation of each item in the Work Programme, and these are written up as **Roadmaps** (typically two pages long for each item) which outline plans for further IA work.

Links to Work Programmes and Roadmaps for 2007 and 2008 are found at: http://ec.europa.eu/atwork/programmes/index_en.htm (Accessed November 2007).

The Guidelines (CEC, 2005) suggest that the depth of the analysis should be proportional to the potential impacts: "The impact assessment's depth and scope will be determined by the likely impacts of the proposed action (principle of 'proportionate analysis'). The more significant an action is likely to be, the greater the effort of quantification and monetisation that will generally be expected". In practice, production of an IA report is still sometimes a superficial exercise carried out to unrealistically tight deadlines, and so having little bearing on the decision-making process. "There has been no formal mechanism for quality control; resources for undertaking assessments, and for the provision of advice, guidance and training are limited; and there seems to be no institutional framework within which 'learning by doing' can take place in practice." (Wilkinson et al., 2004). However, there are indications that the quality of IAs and their significance within policymaking is increasing as the new IA process, launched in 2002, becomes increasingly promoted and adopted within the Commission's strategic programming cycle.

3.1 Which steps would IA contribute to?

It was made clear through interviews with officials in DG RTD that in theory an IA tool should be considered as a contribution to step 4 'analysing impacts' (Fig. 1). Step 5 'comparing the options' can be aided by an IA tool, but the decision on which option to recommend is a political one. In particular the tool was not expected to help with step 3 'to identify the policy options'. However, the reality is that impact assessment does not always follow these six steps in a clear, discrete way. Hertin et al. (2007) for instance, make it clear that "policies do not simply appear out of the blue" and that "a large part of the visioning/problem definition step may have effectively already been completed long before the drafting of the policy proposal has even started. The fact that a policy is being proposed indicates that action is seen as necessary; it is also often fairly clear at this stage what that policy action should be". For some policies the options are developed in an iterative way alongside analysis of impacts, and stakeholder engagement, since lobby groups scrutinise the 'official' analyses, contribute their own analyses, which may differ, and this leads to refinement of the options. For instance, during an interview, an EC desk officer reported from his experience that there was a "constant back and forth between writing the IA and the proposal taking shape."

An example of an IA where the steps in the process were particularly iterative is the Clean Air for Europe (CAFE) programme, which was launched in March 2001. It is "a programme of technical analysis and policy development that underpinned the development of the Thematic Strategy on Air Pollution under the 6th Environmental Action Programme. CAFE used the RAINS model (Regional Air Pollution Information and Simulation) developed by IIASA" (http://www.iiasa.ac.at/ ~rains/ home.html, accessed November 2007), which provides a consistent framework for the analysis of reduction strategies for air pollutants. One desk officer explained as follows, when asked whether there was much interaction between the consultant using the tool and the policymaker designing the policy option: "It depends on the area. There seem to be different approaches floating around and this helps… the Clean Air For Europe strategy – they have run about a hundred scenarios for the whole exercise… with the acid rain model RAINS and these things were always presented at the member states and there were comments and there were reruns and they have been fighting over the summer... between the different DGs because some of them told the costs were too high so then there were re-runs until apparently now they have a compromise – so this is very interactive. […] But this is a very exceptional case, including the stakeholder and the DG involvement in the data used and the methodology…"

Here is an example where a range of stakeholders was involved (member states, industry, NGOs) in an iterative process. At the other extreme there are policies where the impact assessment is very superficial and almost entirely descriptive with little supporting quantitative evidence. Such an analysis will have been carried out at step 4 in the 6 step process, with no iterations with previous steps because there was no meaningful dialogue with stakeholders. Examples were given by Wilkinson et al. (2004).

Interestingly the RAINS model now has two versions: one for scenario analysis (i.e. Fig. 1, step 4), and one that allows the options to be developed (i.e. Fig. 1, step 3). Thus, as explained on the IIASA website, there is a 'scenario analysis' mode, i.e., following the pathways of the emissions from their sources to their impacts. In this case the model provides estimates of regional costs and environmental benefits of alternative emission control strategies. There is also now an 'optimisation mode' under development to identify cost-optimal allocations of emission reductions in order to achieve specified deposition and concentration targets; in other words to allow the user to refine the policy options.

To conclude, end users may wish IA tools to be applied in some contexts to help develop the policy options, in addition to its use to analyse impacts of policy options.

3.2 Timing and depth of analysis

There is a small window of opportunity within the EU policymaking cycle during which analysis of impacts of policy options can be carried out. If desk officers want an external contractor to contribute to an IA the Commission would typically organise a framework contract. There may be a call from the Commission in, say, June, and they may expect the contractor to deliver, say, by August. This is a very short time period in which to operate an IA tool, especially if it requires any additional programming. Desk officers acknowledge that this procurement procedure is not particularly conducive to research needs in support of IAs, including the use of IA tools if their use requires re-programming, and running by experts, to provide results of use to policymakers.

A related question concerns the level or depth of analysis that an IA tool should operate at. There is clearly a need for a 'quick and dirty' tool that could be applied immediately to a wide range of policies without any additional programming. "IQ Tools" (http://www.sussex.ac.uk/spru/1-4-7-1-3.html accessed November 2007) is such a first screening resource, but it has a very broad scope - beyond land use. Officials in the Secretariat General have argued more than once that we should 'keep it simple' and adopt a 'light' approach. In contrast, others, e.g. researchers at JRC, have said that the analytical framework used in the demonstration given to JRC in 2005 was not sufficiently sophisticated. Ideally the 'operating system' for the tool would be able to function on perhaps three different levels:

- A superficial level which doesn't require reprogramming and works for a wide range of policies and could be used immediately by trained desk officers.
- An intermediate level which requires several weeks' work to programme and run the tool for a particular policy area.
- A strategic level where the tool is being developed and programmed for one or more policy areas and used over successive years to contribute at particular points in the development of specific policies.

These are not necessarily mutually exclusive. Different versions might be made available to meet these different needs.

3.3 Who would use SIAT?

We need to distinguish between at least three different kinds of users (see Backlund and Martinson, 2005 for a broader typology applicable to the SEAMLESS project):

- Desk officers who may become trained to use SIAT, perhaps in a simple form.
- Experts who programme and run SIAT in a more sophisticated form on behalf of EC desk officers.
- Other stakeholders who may wish to use SIAT to confirm or challenge conclusions made by desk officers or contracted experts.

We focus here on the desk officers and experts; we can probably assume that other stakeholders will rapidly take an active interest, and learn to use SIAT, as soon as they discover that it is being used to support impact assessments of European policies. Disseminating SIAT to them is thus not the immediate priority.

It is not easy to identify who the end users would be without also identifying how the tool will be disseminated to potential users, how they might be trained, and how SIAT might become accepted and trusted among key stakeholders in a particular policy area. The history of use of the CAPRI model (http://www.ilr1.uni-bonn.de/agpo/rsrch/capri/faq_e.htm accessed November 2007) is instructive. Its life began with external experts, but it gradually moved into mainstream use in Commission DGs, who now provide training courses to desk officers in how to use it.

Thus, in answering the question 'who would use SIAT', we can identify three main scenarios for how it might become adopted and used. These are extensions of the three levels of analysis outlined above. Again, they are not mutually exclusive.

a) Immediate use by individual desk officers
Individual desk officers may become trained in the use of SIAT and able to run it on a policy area. In each DG there may be one or two staff from the unit(s) that specialise in impact assessment who have the incentive to be trained in the use of SIAT. Interviews suggest that there would be very few officers who would actually do this, unless there can be a very simple version of SIAT that requires little training. Related to this is the likelihood that only a small proportion of EC initiatives requiring IAs will have a significant impact on land use.
b) Operational use by contracted experts
Individual desk officers may make use of the outputs of SIAT although they don't actually know how to run it themselves. They may request an external contractor to use it to analyse the impacts of options for a particular policy. (Alternatively, they may not be familiar with SIAT until their chosen contractor uses it and informs them about it.)
c) Strategic use by research agencies

An agency could use and develop SIAT in the longer term for specific policy areas, discuss its application with key desk officers in those policy areas, and in doing so the desk officer might commission that agency to carry out an impact assessment and to use SIAT. For example, JRC bioenergy experts could work together with DG TREN. The agency could also be an external research institute, e.g. part of the current SENSOR consortium.

3.4 How do stakeholders participate in the policymaking process, and the IA process?

In forestry (Ministerial Conference on the Protection of Forests in Europe (MCPFE), 2003), the concerns of stakeholders and ordinary citizens are expressed in terms of 'criteria', which could be defined simply as things that people care about. For MCPFE, a framework of criteria and indicators has been developed and agreed upon by European signatories for continuous monitoring of forests at the European scale. For example, MCPFE Criterion 2 is "Maintenance of Forest Ecosystem Health and Vitality", and "Soil Condition" is one indicator of this. At this scale of operation the criteria and indicators may fail to reflect the concerns of particular stakeholder groups in a given location. For instance, a group of local stakeholders (perhaps including expert and lay people), might decide in a particular context that the quality of drinking water is one of their main concerns (criteria). Chosen indicators for this criterion might be water colour, taste and concentration of nitrogen.

Consideration of such an example leads to the question "whose criteria should be taken into account?", and this is the basis for an initial stakeholder analysis. We need to know who will use the impact assessment (IA), and what values they will expect it to embody. As Cashmore (2007) put it "if it is accepted that operationalising sustainable development involves values, then it is logical that democratic processes are employed to debate which values take precedence." *Ex ante* IA should therefore be participatory and we need to research stakeholder views at the appropriate levels, to answer the specific questions relevant to the analysis. For instance, we will need to establish, at regional and national level, how a particular EC policy instrument might be applied. In SENSOR, land use related policy cases are identified at EC level, and the implications are discussed with stakeholders at regional and local levels so as to refine the content of the SIAT.

In the IA Guidelines (CEC, 2005) it is stated that stakeholder participation should take place throughout the IA process. Thus, desk officers are lobbied more or less forcefully and regularly by member states, environmental and social NGOs and industry representatives. They may be seeking to persuade the Commission to develop a new policy, amend or scrap an existing policy, or to influence the direction of a policy under development. Formal consultation periods are organised online during the development of new policies, and the results are then published on the relevant website. During an evaluation of the EU Commission's IA process, carried out by an external consultant (The Evaluation Partnership, 2006): "39% of those who answered (the) question agreed or agreed strongly that the IA system (i.e. why, when and how IAs are undertaken) is easy to follow and understand. However, almost the same number (35%) disagreed or disagreed strongly. Feedback gathered from stakeholders during the case studies indicated that stakeholders' satisfaction with the transparency of the IA process depends primarily on how the stakeholder consultation element was organised… stakeholders who had only participated by providing a response to an online consultation or in written form, generally felt much less well informed about the IA process, its purpose and eventual outcomes. Transparency is much reduced if there is no direct interaction, especially if contributions (and contributors) are not acknowledged, and no feedback is given on how responses feed into the IA process." In the current procedures, therefore, opportunities for consultation within the short time span of an IA tend only to reach lobby groups and activists, and citizens who are affected by the policy are unlikely to contribute directly as individuals to the debate.

In SENSOR, stakeholder analysis began at EC level, partly to establish end user requirements for IA tools, and partly to analyse the institutional status of IA and related tools. The project then turned to the Sensitive Area Case Studies (SACS). The focus here was on "sustainability issues" – initially those issues that were of immediate concern to stakeholders. For example in the Eisenwurzen area of Austria – one of six SACS – some of the points of general concern were: a trend towards depopulation and an ageing population; loss of cultural landscape character; pollution from heavy industry (Morris et al., 2008). The next stage in the appraisal is to consider sustainability issues in relation to specific policy cases. Here, the policy cases themselves will suggest relevant indicators: consideration of a renewable energy policy, for instance, will lead us to look at net greenhouse gas emissions, and relative prices for food and energy crops.

Participatory appraisal techniques are relatively new, and are seeking to share methodological space with well established technocratic-rational forms of appraisal. This is particularly acute in the field of Social Impact Assessment. The "Principles and Guidelines for Social Impact Assessment in the USA", and the "International Principles for Social Impact Assessment", both published under the auspices of the International Association for Impact Assessment in 2003 are sharply contrasted by Vanclay (2005). The U.S. Guidelines are shown to be "positivist/technocratic while the International Principles is identified as being democratic, participatory and constructivist". Such a polarisation is best avoided, and Owens et al., (2004) conclude "the most constructive way forward… is likely to involve careful tailoring of different forms of appraisal to specific problems and situations".

SENSOR incorporates both technical-rational and deliberative-participatory approaches. Although such a combination has been widely advocated, exactly how to design a mechanism to achieve this is yet to be described. As Stirling, 1999 (cited in Owens *et al.*, 2004) puts it, public deliberation supplies "the essential empirical inputs concerning the selection, definition and prioritisation of the appraisal criteria." However, this does not preclude the technical analysis of environmental problems or the assessment of numerical scientific or economic indicators. It does imply however, that social science methodologies are required to analyse the meanings stakeholders attach to such information. This fusion of participatory and technocratic methods is one of the fundamental aims of SENSOR. It is a challenge, since according to Pope et al. (2004) "there remain very few examples of effective sustainability assessment processes implemented anywhere in the world." These authors emphasise the importance of considering the interactions between social, economic and environmental impacts, since the combined effect of such impacts is unlikely to equal the sum of the parts. For instance, a shift from agriculture to forestry might have the immediate effect of reducing direct employment (socio-economic) and improving biodiversity (environmental). However the improvement in biodiversity might also create new jobs in conservation and tourism. This example also reveals a dilemma. TBL appraisal might indicate the option with the greatest net benefit, but benefit to whom? In the example, the people who lost jobs in agriculture are unlikely to be the same individuals that gained jobs in conservation. The process of arriving at a favoured solution is therefore essentially political, and needs to benefit from local knowledge of the likely impacts (Morris et al., 2008).

4 Conclusions

Impact Assessment is an increasingly important part of the EC policy making process, and there is currently a strong push to develop suitable tools in a rapidly changing administrative environment. This dictates the need for flexibility and for a method of working that is communicative at the full range of scales from EC level to local level. It seems likely that SIAT will have to be applied at various levels of complexity, and that the tool needs to be sufficiently flexible to cover all three potential user scenarios:

1. Rapid screening by (or for) individual desk officers in situations where SIAT is already populated with the parameters of the policy case in question.
2. Operational use, e.g. over a period of several weeks by a contracted expert organisation, giving a limited opportunity to re-programme the tool to suit the particular policy questions posed in the study.
3. Strategic use by a research agency, on an extended timescale (1-3 years), allowing the tools to be reconstructed so as to explore a completely new policy area.

It is also clear that a participatory approach is needed because the impacts of policies are often complex and crucial detail about sensitivities is not visible at the macro-scale. At this large scale, the current consultative arrangements that the EC has put in place are effective in incorporating the views of member states and the major NGOs and interest groups. However, some further studies are needed, especially as part of a land-use related IA, to examine and test the predicted impacts in the light of local knowledge. A key challenge for SENSOR is to develop methods that integrate participation with citizens who are 'impacted on' into the use of the SIAT. This may only be possible when SIAT is used and developed over longer time spans (i.e. as part of a strategic study rather than as part of an operational IA), because of the time taken to engage in this way. However, this would be an effective approach in extending participation beyond the circle of well-known activists.

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An institutional analysis of land use modelling in the European Commission

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Abstract

The paper aims at describing the environment, actors, practices and dynamics in the context of the European Commission's Impact Assessment procedures into which a quantitative ex-ante policy assessment tool of land use changes has to be introduced. Both fields - Impact Assessment and land use modelling tools - are only now evolving. The institutions that guide the choice of modelling tools in the IA process are rather unclear. However, if results of the development of modelling tools are to be used, fit to their institutional environment can be enhanced by understanding this setting. This paper is based on problem-centred interviewing at different EC levels, which focussed on these issues. The purpose was to understand the context into which the Sustainability Impact Assessment Tool, which the SENSOR Consortium currently constructs, will be introduced in the European Commission. The paper concludes that the choices of desk officers are informed by their motivation to produce successful policy proposals. Modelling tools that are usable for the Commission's Impact Assessment furthermore have to be plausible and transparent. They have to rely on official data. Often the use of modelling tools is scrutinised in a variety of fora. Land use issues and the like are of minor importance to the European Commission's Impact Assessment as land use is not perceived to be a competence of the European Commission.

Keywords
land use modelling tool, ex-ante impact assessment, modelling tool selection, policy making process, land use policy, science-policy interface, institutional analysis

1 Introduction

The aim of the SENSOR project is to develop ex-ante Sustainability Impact Assessment Tools (SIA Tool) that allow estimating benefits and trade-offs of land use changes. Located at the science-policy interface, research in SENSOR is to be used in policy making processes at European level. The project has therefore to deal with this end user environment in order to make its research results usable by the European Commission. The paper aims at describing the approach used and the results achieved in analysing the environment in which the SIA Tool is to be used.

At the level of the European Commission decision making on policies is supported by a process of Impact Assessment (IA). A modelling tool, that seeks to inform political decisions about their likely impacts and to make the complex interrelations that shape regional sustainability in Europe explicit, will need to fit into this environment. Both, complex land use modelling tools to evaluate sustainability impacts at regional level across the European Union as well as IA are recent scientific and policy fields. It is the aim of this paper to present the results of the Institutional Analysis that was carried out as part of SENSOR. The operational environment into which the SIA Tool is to be embedded, the actors, practices and dynamics will be described as they shape the way the SIA Tool may be used. These insights allow for conclusions on some of the characteristics that a land use modelling tool such as the SIA Tool should have to be valuable for its potential users.

IA and land use modelling tools - are only now evolving. The institutions that guide the choice of modelling tool use in the IA process are still unclear. However, if results of efforts to develop ex ante quantitative assessment tools are to be used, fit to their institutional environment can be enhanced by understanding this setting. Therefore, in this paper we aim to uncover the regularised, informal or formal rule-guided practices and routines (institutions) that guide ex-ante assessment tool selection with regard to land use impacts of policies in the European Commission. For this purpose we describe the arena in which the choice of ex-ante assessment tools is undertaken.

Literature on IA in the European Commission starts to grow. By far the most comprehensive account of the literature and current status of knowledge on IA have been provided by Renda (2006). Similar to most other studies he evaluates the quality of extended IA reports by applying a scorecard system and he includes the review of other similar studies assessing the quality of extended IA reports (see for example EAAC, 2006; Lee and Kirkpatrick, 2006; Wilkinson, 2004; Opoku and Jordan, 2004). Torriti (2005) furthermore studied the use of quantitative modelling tools in a quantitative fashion and Radaelli (2007) studied the way IA affects regulatory activities, the actors involved and their output. None of the studies cited dealt with what shapes the way an IA is developed by the Commission and more specifically what determines if a quantitative modelling tool is used throughout IA. More instructive in this respect have been studies undertaken by Eckley (2001) and Jäger and Farrel (2006); see also Farrel et al. (2006). They look at overall assessment exercises, of which modelling tool use is only one part. These authors found that three features are relevant in determining the effectiveness of assessments with regard to significantly influencing an issue domain: 1) salience 2) credibility 3) legitimacy. However, the question of what makes modelling tool use effective is quite different from what makes a tool being used, which is what we deal with here.

First the paper outlines briefly the approach to conceptualising the setting into which ex-ante modelling tools are to be introduced and the methodology that the study used to make useful claims about the relevance of land use modelling for European policy making. Second we briefly treat its context, general IA practices. Subsequently we describe the arena in which ex-ante land use modelling tools are selected in the European Commission. This description includes a section on criteria applied for the selection of a modelling tool. It is rounded off by a description of the way modelling tools are used throughout policy development in the EU.

2 Conceptualisation of land use modelling tool use in European policy making

At the time this research was undertaken, it was not decided yet what the tool, whose institutional fit we assess, would exactly look like. As a matter of fact, along with other streams of SENSOR work, the analysis presented in this article contributed to its design. It was assumed that a “land use modelling tool which may be extended by participative methods” is the conceptual core of the modelling tool SENSOR develops.

The assessment tool selection process we look at is part of broader IA. The research and other authors showed that IA practices vary widely in relation to issues such as type of policy proposed, the stage in the policy formulation process, subsidiarity principle, sectoral and geographic scope of the measure, amenability to quantitative and qualitative analysis, the culture and mission of the lead DG, external expertise and consultations with stakeholders (see also Lee and Kirkpatrick, 2006). The paper conceptualises the interactions of the European Commission with further participants in IA and the choice of quantitative modelling tools using Ostrom et al.'s (1994; Ostrom, 1998 and Ostrom, 2005) Institutional Analysis and Development (IAD) frameworki. Institutions structure the setting in which the decision about policy assessment tool use is taken. They are conceptualised as regularized patterns of social interaction which may be formalised in written form and which establish acknowledged or unacknowledged guidelines to people's behaviour (see also: Peters 1999). A difficulty was that the unit of observation involves high-level policy experts/ officials. Confidence of the interviewee and confidentiality about the sources is key in such an empirical setting (Gillham, 2000). The aim was in-depth understanding of the action situations with which European official are confronted. Interview data was triangulated throughout further interviews and with written documents in order to increase reliability. Empirical work consisted of 26 semi-structured expert interviews (snowballing and targeted approach[1]). The research addressed land use and environment related units in DG Regio, Agri, Enterprise, Transport and Energy and Environment, horizontal units dealing with IA, participation, modelling and evaluation in the same DGs and in the Secretariat General of the Commission[2].

Furthermore, it was methodologically difficult to deal with the fact that IA is a very recent practice and the number of cases of IAs, which illustrate the issues the study was interested in, is very limited. Land use mod-

[1] As it emerged throughout the research IAs on some substantive policies were of specific interest: The Cafe (Clean Air) IA, the Reach (Chemicals policy) IA, the Soil strategy IA, the climate change policy, the five thematic strategies that DG Env issued in 2005 (urban environment, sustainable use of resources, protection and conservation of the Marine Environment, Prevention and recycling of waste, air pollution).

[2] Interviews were carried out in the following units: 9 DG Environment, 4 DG Regio, 1 DG Research, 3 DG Agri, 3 DG Enterprise, 1 DG Joint Research Centre, 1 DG Tren, 1 Secretariat General of the European Commission, 1 Secretariat of the European Council, 1 administration of the European Parliament, 1 European Environmental Bureau, 1 European Environmental Agency. Additionally, two experts in EU IA practices were interviewed.

elling tools are innovative to an extent that the issues they touch upon have barely been considered before. Therefore, we opted for assessing several of the features of the land use modelling tool in relation to European policy making in general. The research and questionnaires addressed the following overall research question and subquestions for the Institutional Analysis of the use of land use modelling tools throughout IA.

Box 1. Research Questions of the Institutional Analysis

> What is the environment into which the land use modelling tool will be introduced? Based on this data the following question are to be answered.
>
> <u>*Overall research question:*</u>
>
> What makes the European Commission use a specific quantitative modelling tool for ex-ante policy assessment?
>
> <u>*Subquestions:*</u>
>
> 1. How does IA work as the context of policy assessment/ development in the European Union, into which the land use modelling tool is to be introduced? What indications can we draw from this for the organisationally interlinked arena in which ex-ante assessment tools are chosen?
> 2. What rationale underlies the way desk officers select a specific tool?
> 3. What features of the policy, that is assessed, matter to the selection of a specific assessment tool?
> 4. Which features of an assessment tool influences whether it is selected?

3 Context of IA practices

IA practices in the European Commission are evolving fast[3]. Generalisations with regard to how an IA develops are impossible to make as all desk officers highlight. The way IA develops depends on the type of document that is being assessed, and the characteristics of the policy, i.e. the interests that it impinges upon, and its specific implications. IAs are increasingly scrutinized outside of the Commission and in formal sessions in the other EU bodies that participate in policy development (European Parliament and European Council of Member States).

Participation and consultation as an integral part of IA serves to clarify the nature of the problem, objectives, policy options, impacts, or comparison of policy options of IA. “Target groups and sectors which will be sig-

[3] For a further description of the contextual development of IA see also Renda (2006) and Thiel (2008).

nificantly affected by or involved in policy implementation, including those outside the EU" (CEC, 2005) should always be included. Desk officers confirmed that in some cases IAs justify political decisions that have already been taken by the time the IA is done. Such an IA 'legitimizes' policies ex post instead of 'contributing' to policy development ex ante. Reasons can be that some of these policy domains are subject to more inter-governmental styles of policy development (see also: Fligstein and McNichol, 1997). Another set of IAs influence the outcome of policy making at least to some extent. They are an attempt to design the policies to reach a specific goal and minimize its negative effects on the various stakeholders and sustainability. Often the policies and IAs in the category of 'contributing' IAs were driven by the Commission. Contributing IAs are considered to be equivalent to the policy development process. In the following we exclusively look at 'contributing' IAs which are part of the ongoing policy development process.

3.1 Participants involved in Impact Assessment at EC level

Participants, in what Ostrom (1998; 2005) would call the quantitative ex-ante policy assessment tool selection 'action arena', are those actors that influence if a tool is used throughout policy assessment procedures, and which one is used. Participants in IA are also potential participants in the tool selection arena. They comprise desk officers in the European Commission and the hierarchy that legitimises their decisions. Furthermore, the European Parliament and the Council are participants in adopting legislation. Their influence depends on the voting procedure[4]. Finally, consultants and experts may be asked to provide input to an IA. In the study the role of the voting procedure was specifically noticed in the context of the agreement on Regional Policy in which the Parliament plays a less significant role than in policies developed by DG Environment, Transport and Energy or Enterprise. This was one of the reasons why the IA associated with this policy was less well developed and less debated than in cases of policies originating in DG Environment or Enterprise. Policies that are principally decided by the Council are less open to debate with stakeholders as indirect participants in the development of legislation.

The overarching norms of behaviour of the community of participants in IA are determined by the actors that directly participate in European law-making. However, these rules need to be acceptable to the outside, to

[4] *Co-decision procedure*, *cooperation procedure*, assent procedure (see also: http://www.europarl.europa.eu/facts/default_en.htm#, accessed: 29.6.2007)

stakeholders and those legitimising the Commission and the Council. It can be assumed that the preferences of these actors with regard to the substantive policy outcome vary significantly. Similarly, the resources of the various members of this community to influence policy development vary and depend on the voting procedure among the participants (Council and Parliament) in the legislative process for the specific policy field. The Commission has significant influence as it has the right of initiative in European policy making and guides the policy development cycle and the associated IA. Because of its limited human resource capacities the Commission outsources significant amounts of work to consultants. Depending on the type of legislation that is to be adopted, the European Council and the Parliament have varying possibilities to express themselves on the proposal, adopting or rejecting it or sending it back to the Commission for alterations.

The detailed properties of the actors vary significantly. The research confirmed that the task of Commission staff shifted increasingly from policy formulation to a 'catalytic research activity' and the use of policy analysis as a means of persuasion, while it always seeks to extend the scope of the Commission's role (Cram, 1997). Desk officers usually do not have a substantial programmatic preference with regard to policies. For career purposes, gains in wage and prestige, their objective must be to have policy proposals adopted by the various levels of the hierarchy of the Commission and subsequently by the European Council and/ or the Parliament (Hooghe, 2001). Delivering solutions to the puzzles of European policy-making attracts attention of senior staff that is necessary for promotion. Therefore, the community that participates in IAs that contribute to policy development shapes the way IAs unfold more than the specific substantive outcome a desk officer has in mind. Nonetheless, career advance is strongly affected by the time officers serve in the Commission.

Substantive preferences of desk officers with regards to policies are secondary in the way they develop policies. They are shaped by desk officers' membership in a specific DG and by their previous education and experience (Hooghe, 2001). These characteristics of desk officers vary significantly. In the case of good IAs, that contribute to policy content, the preferences of desk officers are shaped by the ongoing IA and policy development. Desk officers inform themselves about the impacts of the policies and the substantive preferences of stakeholders that the policy impinges upon, and about ways to assess them. On the other hand desk officers hardly have the time to do extensive assessments themselves. As certain questions are raised throughout steps of policy development, consultation and lobbying, desk officers learn about the policy, its implications, the interests they impinge upon and they develop answers to them.

Providing answers to the questions that emerge throughout policy development is about assessing the impacts of a policy. It influences its contents and its chances of being adopted. Choices about what impacts are being assessed, how, can be assumed to have an impact on the policy outcome and its potential for adoption. For this reason assessment choices are widely recognised as matters of debate and political relevance. Desk officers guide policy development, which gives them considerable influence. Nevertheless, they have relatively less control over the policy making outcome as it has to be approved by many levels of the hierarchy and several entities (Commissioners, Council, and Parliament).

More senior officials are more aware of the political implications of a proposal (Stevens and Stevens, 2001; see also Hooghe, 2001). This assures that officials act in line with DG priorities. Senior officials have greater control of the outcome of policy making than desk officers given their greater authority. Senior officials' interest and influence on technical details varies with the different personalities involved (Cini 1996).

Other participants, such as stakeholders, consultants and experts have no direct influence either on policy development, its adoption or IA. Stakeholders may exercise considerable indirect influence over the way assessments are undertaken and the content of policies. Resources of stakeholders vary widely, with environmental NGOs often being underfunded and some private sector interests having significant resources at their disposal. Regions and their European representations are only developing a position where a policy has impacts on a specific region. For consultants, experts and stakeholders it is assumed that information and processing capacities are concentrated on substantive, technical issues, rather than on political issues.

4 Actors’ tool selection criteria

As European officials are uncertain about the implications of their choices they apply a set of criteria to select a modelling tool. They are the outcome of their experience of the political process. Partly, they are codified in the IA guidelines of the Commission. Others were ‘institutionalised’ on the basis of the experience of desk officers. Following them makes sure that the tool is beneficial for successful adoption of a policy.

4.1 Quantitative modelling tool use?

Above we already described the principal advice provided by the IA guidelines regarding modelling tool use, based on the principle of proportionate analysis. From our insights into IA and the above, we conclude, that with regard to the use of ex-ante assessment tools, a key issue is whether the tool answers a question that is relevant for developing/ assessing the policy and making it acceptable. Relevance is determined throughout the consultation and participation processes associated with IA. With regard to ex-post evaluation, for example, an expert meeting in Brussels concluded: "there are a very large number of various types of modelling tools available while on the other hand, their applicability to the questions relevant for evaluations of public policies is limited" (CEC, 2002d). Therefore, we have to investigate what questions are relevant for policy development, and what role land use implications play in that context.

The empirical work confirmed that extensive modelling is only done for salient, policies, where significant impacts are expected, and where we deal with a new regulation or substantial amendment or expenditure programme. It is unlikely that extensive modelling will be done for white papers, for example. Quantitative analysis can be done on its own or complemented by qualitative assessment. Questions that emerge as relevant to a policy proposal, also outside of the issues the sector focuses upon, will be assessed. Unintended impacts and issues over which the Commission does not have any competence were referred to as being specifically important.

4.2 Relevance of land use, landscape and multifunctionality in assessment

Looking at the current work programme of the Commission, land use implications do not figure prominently. An observer may find such an assessment useful in maybe a handful of cases. In most DGs desk officers understand the land use implications of policies. On the other hand, despite the table of questions included in the IA guidelines that addressing land use related issues, in practical policy making it seems to be of less relevance. Land use assessment is perceived as unnecessary by most DGs, except DG Agriculture. In DG Environment, the reaction to the assessment of land use implications was sceptical. It is seen as principally associated with biodiversity protection, soil (and therefore agricultural) policy and with the environmental dimension of regional policy. With regard to soil policy, there seems to be the attempt to keep land use issues (or the territorial dimension, as it is called in EU jargon) out of the regulation that is currently being developed. Similarly, it is highly contentious if sealing of soil should be tackled as part of the soil strategy as well as it is contentious as indicator for monitoring environmental programmes (see for example: EEA, 2005).

Land use is considered to be a touchy issue for European policy making, as it is an issue of unanimity voting. An assessment of land use implications was not undertaken as part of the IA for the new Regional policy instrument, the Structural Funds covering 2007-2012. Land use implications are said to be a matter of implementation of the funds which has lately become the exclusive responsibility of the MSs. Tourism development, which is one important land use implication of many Structural Fund projects is a 'negative priority' of the Commission. Therefore, DG Environment has awarded the human resources to deal with tourism from an environmental perspective.

DG Regio similarly seems to have little interest in assessing impact on land use at the regional level. Previously it had a framework contract concerning a model that could evaluate the spatial implications of fund allocations on the regional level[5]. It has meanwhile withdrawn from this contract and now concentrates on modelling macro economic impact and regional economic growth as a consequence of the regional funds. DG TREN also seems to have little explicit interest in taking up the issue of land use implications. DG TREN and REGIO have contracted some studies of spatial implications of projects from the JRC. Some of them are confidential. DG Agriculture is most explicitly trying to look at implications of its policies for land use. However, in fact they exclusively worry about land use management issues on agricultural land.

The assessment of impacts on landscapes seems to be even less relevant for policy making. Most respondents associated it with the aesthetics of landscapes rather than with the systemic components of landscapes used in SENSOR. Currently, landscape in the former sense, as well as the European Landscape Convention, are not of great relevance to policy making for the Commission, now and in the near future either. They are assumed to be mainly national issues.

Finally, multifunctionality is barely known in the European Commission. People in the agriculture policy domain are aware of the concept but give little significance to it for policy making. Semantics matter in this regard. For the European Commission multifunctionality is associated with supranational negotiations in the context of the World Trade Organisation (WTO) and the changing role of agriculture for society (see Garzon, 2005).

[5] Rime

As a consequence of these negotiations today the concept seems to be avoided by the Commission altogether. In fact, Europe seems to be hesitating between multifunctionality – with its emphasis on the functions of agriculture – and sustainable development – and its emphasis on policy goals" (Garzon, 2005). Some European officials associate it one-sidedly with the environmental side of sustainability, or see it as not clearly defined. As a descriptive concept it is too vague and as a normative concept it makes unclear prescriptions. Furthermore, a normative version of multifunctionality is not politically supported by the MSs. The European Environmental Agency, the Joint Research Centre and DG Research seem to be much more interested in the analysis of land use issues and multifunctionality.

4.3 Further criteria for tool selection

Desk officers value further issues in a modelling tool useful for policy development. Of great importance in this regard is that the results of the use of the tool are *plausible*. This means that the results make intuitive sense. Plausibility is more important for models that the EU uses than the degree of innovation they achieve. If they have a doubt with regard to an aspect of a model experts from MSs and regions would question the overall model which can make the analysis worthless for policy making. Where plausibility is not achieved, desk officers would contact modellers to understand what causes such implausibilities. It may be more useful to give a range of results or even to run models several times and to explain the results. Also, sensitivity analysis is a good way to evaluate the results.

Much appreciated '*user-friendly'* models. This means that desk officers can use them themselves after brief training. However, desk officers are aware that often the assessment of a specific issue requires complex modelling. In this case it is important to take 'the lid off the black box'. This implies extensive training of desk officers with regard to the underlying assumptions of the model, its drawbacks and potential, so that they are able to defend the results of a modelling tool in a political process. In 'good practice IAs' such training also involves the main stakeholders. However, such efforts are usually only spent on the most significant policies.

Modelling tools that are used by the Commission should be *transparent,* which means that the way in which impacts are estimated has to be made explicit. Furthermore, they must be reproducible by others, and data, results and methods have to be double-checked. Finally, all problems of the tool, the assessment, the assumptions, the restrictions, risks and weaknesses associated with the tool have to be made explicit (CEC, 2005). The Commission in fact sees the *intelligent combination of quantitative and qualitative methodologies* as good practice (all interviews). Furthermore, the tool must be *transparent with regard to the data* that goes in and the way the data is modelled, the scenarios, the validation and baselines etc. After a modelling tool has been used, much of the discussion within the Commission and with stakeholders focuses on these issues. The tool obviously has to be *up to date*. Models should have a *good scientific track record*. Often they are specifically peer-reviewed by experts nominated by various sectoral interests. Such a review may also include the way the tool is run by the consultant and the data that is used. If possible desk officers tend to rely on adaptations of tools with which the Commission has *already gathered experience* or which were co-funded by the Commission.

Furthermore, desk officers state that they appreciate if they are *consulted throughout the development* of a model. This can make the model more relevant to their needs. However, often the problem is lack of time and the fact that only their successors would benefit from input into tool development. In order to increase the acceptance of a model within the policy development community, desk officers suggest to present models for future use by the Commission to stakeholders and the MSs. The Commission itself writes "[g]ood communication of the research teams with the European Commission on the availability of statistics, statistical requirements and new developments in statistical systems at the European Commission will also foster the use and development of ex-post modelling tools" (CEC, 2002d). Desk officers acknowledge that *modelling can be very useful* in policy development. It changes the debate and makes it focus on technicalities of how to achieve an objective most effectively.

4.4 Data

Information is a vital component in any political system (Sverdrup, 2005: 3) and providing a space of common measurement, within which issues may be compared, is part of creating a polity. Trust in the quality of information, and the institutions generating information, is important for securing trust in government and democracy. In turn "[n]umerical information has become increasingly important in EU decision making…[as] European statistics are distributed more widely, are more frequently used and are generating increased attention" (Sverdrup, 2005).

All desk officers, as well as the guidelines, consider data one of the most important constraints to the application of modelling. Often data is not available at all or it is not reliable and accepted by the policy development community. Also, desk officers warn of data that comes from stakeholders as they may try to influence the process (CEC, 2005). At best modelling relies on ESPON or EUROSTAT data[6] or official national statistics. Consultants should only gather their own data in exceptional cases. In some case the needs of an assessment may be too short term to be met by the data available so that an assessment has to justify its arguments differently.

With regard to the availability of Europe wide spatial data sets the Commission describes the situation as rather poor on the European and national/ regional level[7].

In order to tackle these problems the European Commission initiated INSPIRE (Infrastructure for Spatial Information in Europe). Whether or not INSPIRE is agreed to its final form and the arguments which are presented throughout its development will be of great relevance for land use modelling and IA.

4.5 Visualisation of results and disaggregation

DG Agri and DG Env underline that the way in which data is presented depends on its characteristics. In both policy areas this often includes mapping of impacts. Environmental NGOs see mapping and highlighting the effects of policies or status quo with colours as beneficial for their policy aims. It is specifically effective in making policy makers aware of issues and giving them an incentive to act. The Commission seems to be free to choose the way it wants to present the results of its studies. In DG ENV, maps are sometimes deliberately used publicly, to put pressure on badly performing regions and MSs. In DG Agri their use does apparently not pose any problems, which may have to do with the fact that this is a policy that is the exclusive competency of the Commission. A policy domain that seems to be more sensitive in this respect is Regional policy. Studies that take recourse to maps have to be transparent about their origin and make the unofficial character of maps explicit. Often, DG Regio decided to only

[6] Even Eurostat data has been accused in the past of providing systematically biased statistics in favour of specific policies or outcomes (Sverdrup, 2005).

[7] "absence of agreed and transparent policies and mechanisms for access and reuse" of data, "project based approach to data that leaves gaps and, at the same time wastes resources by duplicating data collections that cannot be fully reused; no framework for regular updates, …, patchy interoperability of data; poor return on investment because projects are always one-off and not well integrated (CEC, 2005b).

present very descriptive dimensions in the form of maps, such as for example population or demographic statistics.

Where maps are used as a basis for policy-making, desk officers confirmed that they may be highly contested by a variety of stakeholders and therefore may best be avoided altogether. Reasons are that: Land use planning is a national competence that is to be maintained that way. Land use development mapping and planning is associated with economic development perspectives which may gain a symbolic character when they rank regions. The empirical work could not clarify to what extent these issues play a role in mapping in the context of IAs.

The data and its representation can be disaggregated by the Commission as necessary for its purposes (e.g. grouping together parties to the negotiations of a directive).

The empirical work similarly investigated how regions or nation states react to assessing their performance, specifically in regard to policies. Desk officers see no problem with such an assessment at the stage of policy design. On the other hand, the way regions and MSs are assessed, including which indicators are used, may be contested in the context of monitoring the performance in terms of implementation of regulations and programmes. In the context of IA this step would be part of outlining the problems a policy initiative aims to tackle.

4.6 Interaction with regions and regional stakeholders

Regions and localities are specifically important in land use modelling due to its spatial dimension. For this reason the Institutional Analysis decided to look at their relevance in policy development. However, the role of the regions and regional stakeholders in overall structured consultations is very limited. Despite the fact that European Regional policy adheres to the 'partnership' principle[8] the role of regions varies throughout the policy making process. It has had little impact on the policy design stage (IA) while it has been significant at the planning and implementation stages of European policy making (Thielemann, 2000). Regional stakeholders usually only get involved with regard to certain specific regional issues (e. g. environmental problems) or projects (e.g. projects co-funded by the European Union). Formally, when the Commission wants to find out about a

[8] One of the Structural Funds principles which implies the closest possible cooperation between the Commission and the appropriate authorities at national, regional or local level in each member state from the preparatory stage to the implementation of the measures (CEC, 2006a)

region or deal with a problem in a specific region it has to address the "competent authority" on the national level. When it was launched IA was highly welcomed by the CoR. It specifically pressed for a regional dimension of IA practices[9].

5 Implications of tool use for Impact Assessment in EU policy making processes

In this section we describe the way modelling tools are used throughout IA in the European Commission. In 'contributing' IAs concerning salient policies, the tool, the data and the scenarios that are used would be extensively discussed within the Commission (see also Sverdrup, 2005). Scenarios may be approved within a directorate before use. The outcome may be checked with experts from the MSs with regard to its plausibility. Key is that desk officers themselves are able to explain the way a model produced its outcomes. Assumptions are also regularly subject to extensive scrutiny and discussion. For this purpose the Commission holds meetings among the services involved, with participation of the consultants that performed the modelling and sometimes stakeholders. Consultancies and the Commission may be asked at this occasion to "open up the black box" and make the operation of models transparent.

The Commission aims to "close issues" by adopting a final position on the best way of modelling or how the results of modelling should be viewed. It may also agree with stakeholders on how to study unresolved issues in more depth.

For specifically salient policies, modelling tools and their results may be discussed with representatives of the MSs or the Parliament within the legislative process between Council and Commission (see also above). Tool use is never unquestioned where policies involve significant stakes. Tool use changes the discussion and focuses it on the assumptions that are made throughout policy development. Also, "[c]ompared with textual information, figures are particularly effective in reducing complexities and enabling comparisons… Numerical value also seems to affect the value and trust attached to the information. …[on the other hand in the EU the lack of a common language makes textual information even more difficult and costly …but numerical information creates a form of communicating across fairly heterogeneous member states" (Sverdrup, 2005: 5) Some po-

[9] Presentation by Commission desk officer on IA in the European Commission refers to the opinion of Report on better law-making.

litical representatives instrumentalise them. Others are reluctant to take their results on board altogether. The latter argue that decisions, once they reach the political level, should be made on a political basis rather than on the basis of quantitative evaluations.

6 Conclusions

Our conclusions have to be treated with considerable caution as a) land use modelling in the Commission as part of IA touches on uncharted territories, b) the setting (IA) into which it is introduced is highly dynamic as political priorities may well change and c) to some extent this setting may also reflect innovations such as specific land use modelling tools. Each IA is different. According to the principle of proportionate analysis only IAs regarding salient new regulations, substantial revisions or expenditure programmes require in-depth modelling.

The primary aim of desk officers is to have policies adopted. Substantive preferences are subordinated to this objective. It is motivated by career advancement, which implies gain in remuneration and prestige. Desk officers are instructed about substantive, sectoral preferences by the 'client group' of the sectoral Directorate General. Participation, consultation and knowledge gathering serve the purpose of informing desk officers and the hierarchy of all politically relevant substantive issues that are at stake with a specific policy proposal. Therefore, throughout a 'contributing' IA, the substantive preferences of the Commission with regard to a policy proposal are partially formed endogenously.

Outcome orientation of desk officers is expressed through the desire to produce a successful policy proposal. Desk officers apply a set of criteria that guide the way they steer policy development and IA. They are partly codified in the IA guidelines. These findings indicate that the logic of action selection of desk officers and the hierarchy is complex. Substantive preferences are endogenously formed through their secondary (temporary) membership in the policy domain involved in shaping a specific policy. Preferences that value career advance higher than substantive policy seem to be relatively stable.

When confronted with the choice of an ex-ante policy assessment tool, desk officers are likely to apply the following criteria for deciding if a tool is used or not: The most important criterion is that only assessment tools are used that answer questions that may emerge or already emerged from the policy development process and that are considered to imply significant impacts. The IA process or they themselves should have concluded that the policy in question has significant impacts on land use, landscapes, multifunctionality or the like. These effects furthermore have to be identifiable at the corresponding level of disaggregation.

In the past only few policy proposals had such impacts. The issues shaping land use are relatively clear to Commission officials (however, depth of understanding seems to vary significantly). Nonetheless, desk officers seem to have limited interest to do this kind of assessment. This is specifically the case in DG Environment, DG Regional Policy and DG Transport and Energy. Detailed land use impacts are perceived to be a matter of policy implementation which is the competence of the MSs. Furthermore, land use planning is the competency of the MSs. However, some desk officers say that the Commission should specifically look at those impacts where it does not have any competence. DG Agriculture on the other hand has considerable interest in assessing the land use implications of its policies. The Commission does not seem to have much interest in the aesthetic dimension of land use (although related impacts are mentioned in the IA guidelines). The European Landscape Convention does not seem to affect this view.

The concept of multifunctionality is principally known to those who are involved in agricultural policy making. However, it seems to be discredited for a variety of reasons. The impression arises that some of this scepticism towards the concept is based on semantics, or the discourses it is associated with rather than some of its potential substantive meanings. As a consequence policy tools for IA in the European Commission may need to adapt to such semantic considerations.

Further criteria that desk officers apply to the selection of tools are the following:

- the tool has to produce plausible results. This means that the results have to withstand intuitive scrutiny or expert knowledge of the terrain about which the tool makes predictions.
- the tool must either be user-friendly (simple to use) or the way it produces results must be well explained to desk officers. Desk officers have to be enabled to explain the results of an assessment themselves. For significant dossiers, desk officers and stakeholders may attend several days of training with regard to modelling.
- the overall assessment process associated with the tool needs to be transparent. This transparency is the overall most important criterion for tool selection. Some point out that transparency is enhanced if the modelling tool is openly available to all actors participating in the policy

domain. This includes the data, the scenarios, the assumptions made and the calculations that produce certain results.
- desk officers prefer tools that have a good track record in scientific and at best political assessments. If possible they would rely on tools that are already used in the Commission and adapt them to their needs. Stakeholder groups may be asked to select 'independent' experts to review modelling tools, their input and the way consultants run them.

Numerical data is of increasing significance in European policy making and generally favours modelling where this is technically justifiable. However, data sources are closely scrutinised and a tool should at best only rely on official European data sources such as Eurostat or ESPON. The quality and availability of spatially referenced data may be improved significantly by the currently draft INSPIRE directive, which is currently being negotiated. Mapping is welcomed as a way to represent data. The level of disaggregation of the data is chosen in a way that groups data usefully in regard to the question that the Commission has. Regions have a marginal role in policy development so far. If regions want to influence policy making, they either address the Commission or the European Parliament directly or they make the national level act on their behalf.

The findings of this study can be interpreted as confirming those of similar studies documented in Eckley (2001) and Farrel et al. (2006). The results of the described work fed into the design of the SIA tool in a variety of ways. The work helped to reflect SENSOR's position at the science-policy interface. One example is the design and adaptation of the SIA tool according to the criterion of transparency by shaping the interface and including fact sheets on calculation methods, indicators etc. Furthermore, the results are used in the dissemination strategy of the project, since it reveals potential end users' preferences and selection criteria.

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[i] The IAD framework describes collective and individual actors (participants in an action arena) with recourse to their preferences for potential outcomes, the way they acquire, process, retain and use knowledge and information; their selection criteria to decide upon a particular course of action; the resources that an actor brings to a situation. It describes the community of actors through the generally accepted norms of behaviour, level of common understanding about action arenas, extent to which preferences are homogeneous and the distribution of the resources among the community. The IAD singles out position rules, which specify positions of actors and the number of participants that hold each position; authority rules, which specify the set of actions associated with each position; aggregation rules which specify the transformation function that map actions into intermediate or final outcomes; scope rules, which specify the set of outcomes that may be affected and information rules which specify the level of information available at a certain position and payoff rules which specify the costs and benefits associated with certain actions and outcomes. Furthermore, it matters how often this situation will be repeated. However, many policy assessment exercises are so unique that we can assume they are one off decisions.

Ex ante impact assessment of land use changes in European regions – the SENSOR approach

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Abstract

Land use includes those human activities that exhibit a spatial dimension and that change the bio-geophysical conditions of land. Land use policy making at European level aims at fostering sustainability pathways of natural resource use and rural development through the decoupling of economic growth from environmental degradation while supporting social cohesion in rural areas. Targeted policy making requires tools for the *ex ante* assessment of impacts of policy driven land use changes on sustainable development opportunities in European regions. These tools have to cover all relevant land use sectors and impact issues including their interrelations. They have to be spatially explicit, allow scenario analysis of possible future developments, be based on reproducible analyses, and be transparent and easy to use. The European Commission funded Integrated Project

SENSOR is dedicated to develop such *ex-ante* Sustainability Impact Assessment Tools (SIAT) for land use in European regions. SIAT is designed as a meta modelling toolkit, in which global economic trend and policy scenarios are translated into land use changes at 1km² grid resolution for the area of Europe. Based on qualitative and quantitative indicator analyses, impacts of simulated land use changes on social, environmental and economic sustainability issues are assessed at regional (NUTS2/3) scale. Valuation of these impacts is based on the concept of multifunctionality of land use. It is conducted through expert and stakeholder valuations leading to the determination of sustainability choice spaces for European regions. This paper presents the analytical approach in SENSOR and describes the impact assessment framework.

Keywords

Land use, scenario studies, integrated impact assessment, indicator analysis, modelling, participation, land use functions, multifunctionality, sustainability valuation

1 Introduction

Land use changes and their related impacts are the central object of the analysis of this study. The term land use is understood to imply those human activities that exhibit a spatial dimension and that change the biogeophysical conditions of land and the environment. From the spatial viewpoint, land use is among those human activities that have strongest impact on the environment worldwide. Concerns about environmental impacts of land use changes are not new. Extensive literature exists on the relations between land use patterns and intensities and environmental impacts, e.g. soil degradation (Pimentel, 1993; Boardman and Poesen, 2006), desertification (Reynolds and Staffort Smith 2002; Geist, 2005), water quality and biotic diversity (Poschlod et al., 2005). Interrelations between land use changes and ecosystem robustness and resilience have also intensively been studied (e.g. Metzger et al., 2006). In recent years, the role of land use in accelerating/mitigating climate change processes has gained focus (IPCC, 2001, Graveland et al., 2002). Increased understanding of the relations between land use changes and environmental impacts have been triggered by a series of studies related to the Land-Use and Land-Cover Change project (LUCC) of the International Geosphere-Biosphere Programme (IGBP) and International Human Dimension programme on

Global Environmental Change (IHDP) (Lambin et al., 1999). When compared to environmental impacts, social and economic aspects of land use changes are less well understood. They are mostly analysed in the context of driving forces for land use changes.

In recent years, modelling and foresight studies of land use change have emerged that place land use into the logical chain of driving forces and impacts (Veldkamp and Verburg, 2004; Verburg et al., 2006). For example, the ATEAM project (Advanced Ecosystem Analysis and Modelling) has undertaken scenario based simulations on global climate and land use change impacts on ecosystem vulnerability in Europe (Rounsevell et al., 2006). Building upon this study, the EURURALIS project also addressed a choice of socio-economic impacts associated with land use changes predominantly in the agricultural sector (Klijn et al., 2005). The method allowed the anticipation of possible impacts of economic trend and policy choices on agricultural developments and related sustainability issues. Also for the agricultural sector the SEAMLESS project developed an approach for multi-scale modelling to assess sustainability impacts of agricultural policies (van Ittersum et al., 2008). PRELUDE was another study on scenarios for future land use changes in Europe conducted by the European Environmental Agency (Hoogeven and Ribeiro, 2007). Designed as a facilitation instrument for public debate on landscape visions, various stakeholders elaborated a set of antithetic scenario narratives to envision landscape appearance in 30 years time. Extreme and partly shock based socio-economic developments and land use decisions were important features of these scenarios.

The here reported approach of SENSOR can be seen along the lines of the above mentioned studies but aims at developing *ex-ante* assessment tools for policy support that fully integrate social, economic and environmental impacts of policy driven land use changes at European scale. SENSOR "*Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects on Multifunctional Land Use in European Regions*" is funded by the European Commission FP6 framework research programme to develop tools for ex-ante impact assessment for European policies related to rural land use (Helming et al., 2006). To be policy relevant, the approach had to consider simultaneously the spatially relevant aspects of those economic sectors and activities that are involved in rural land use at European level. These include agriculture and forestry as main sectors, transport and energy infrastructure, rural tourism, and nature conservation as a 'regulatory activity' occupying land. In analysing driving force and policy scenarios for medium term perspectives (10-20 years), economy driven land use changes between these sectors and activities, their interrelations and their impacts on environmental, social and economic parameters affecting multifunctionality and sustainable development were to be assessed (Figure 1). This chapter describes the analytical approach of the SENSOR project in developing *ex-ante* impact assessment tools for European land use policies. Its objectives are (i) to provide the context of sustainable development, land use multifunctionality and impact assessment, in which the project is placed, and (ii) to weave the logical thread through the project's analytical design.

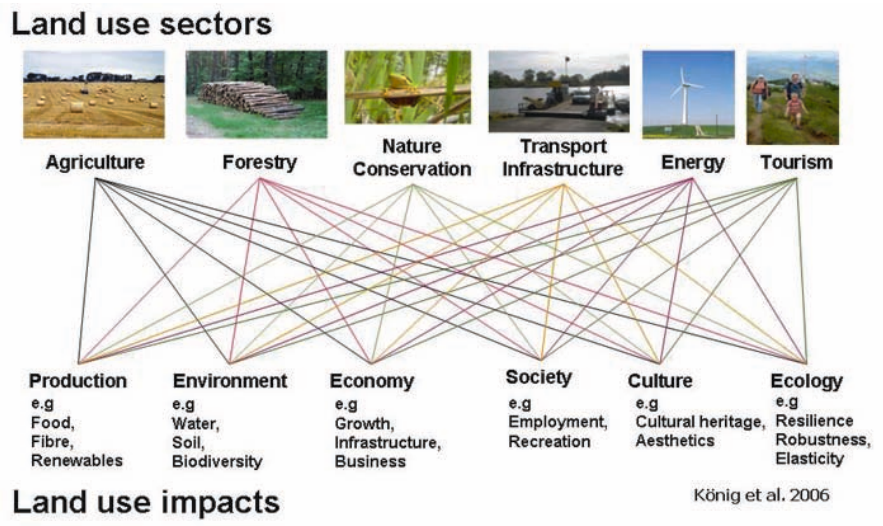

Fig. 1. Land use sectors and impacts analysed in SENSOR.

2 Sustainable development and multifunctional land use

Since the UN Conference on Environment and Development in 1992, sustainable development has been raised to a comprehensive conceptual approach. It has become a pioneering programme for politics to cope with the common future of humankind. This also implies relevancy to the future shaping of rural areas and the development of future land use systems. The significance of the sustainability concept in international debates can be attributed to its use in the Brundtland Commission's report *Our Common Future* (WCED 1987). This report emphasised the economic aspects of sustainability by defining sustainable development as "economic development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.” For the case of agriculture, the term was further defined in the mission statement of the Consultative Group on International Agricultural Research (CGIAR) as “successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources” (CGIAR 1995). The terminology implies a strong normative, value driven component, which makes it attractive for policy makers, but at the same time severely challenges scientific analysis (Becker, 1997). On the one hand, scientific analyses of sustainability focus on the description of states and trends of a system through the determination of environmental, social and economic indicators and parameters. On the other hand, normative visions on ethical considerations, intergenerational equity and development targets have to be considered for valuing these states and trends in the light of deliberately defined sustainability targets. In this regard, sustainable development is interpreted as a procedural concept, in which societal debates on sustainable development targets are substantial features. This is also manifested in the European Commission’s Sustainable Development Strategy (CEC, 2006).

For the case of land use and landscapes, the diversity of natural conditions and cultural systems prohibit the development of universally valid sustainability principles of land use and development. Therefore, regionally specific objectives of land use and land development must be defined that respond to the environmental and socio-economic characteristics of the respective region. The concept of multifunctionality is an attempt to specify the idea of sustainable development for the specific case of land use and landscape development (Wiggering et al., 2003). The underlying rationale for multifunctional land use is to consider social, economic, and environmental effects of any land use action interactively. In other words, commodity production is analysed in the context of its negative and/or positive externalities on environmental and social conditions of a spatial system. These effects are linked to spatially explicit geophysical and socio-cultural conditions of landscapes to provide “functions” or “services” in the landscape context (Costanza et al., 1997; De Groot et al. 2002). They include the provision of abiotic and biotic resources (water, soil, air, biotic integrity), the production of food, fibre and other biomass related products, the regulation, transformation, buffering and storage of energy and matter fluxes, the support of health, education and spiritual values including cultural heritage and recreation, and last but not least the basis for economic growth and social welfare. The multifunctionality of any land use action then lies in the degree to which land use affects the ability of the landscape to perform these various functions interactively (Barkman et al., 2004; Helming et al., 2007). This interpretation of multifunctionality can be confronted with a demand side in estimating societal demands for landscape functions. This would allow assessing the value of multifunctional land use to society. If sustainability is understood as a normative, discourse based process (WCED, 1987), then this multifunctionality concept can be used as an estimate for sustainability assessment of land use. Attempts have been undertaken to employ this concept (Helming and Wiggering, 2003; Cairol et al., 2005; Mander et al., 2007). The SENSOR approach for impact assessment is also based on this concept.

3 Impact Assessment tools for European policy making

Ex-ante impact assessment for European policy making is devoted to two major purposes: (i) better regulation and (ii) sustainable development (CEC 2005). The first item addresses the effectiveness and efficiency of the intended policy intervention with regard to the policy target (e.g. food production, rural development, conservation of natural resources). A number of tools and methodologies are available to analyse these questions, predominantly those based on Standard Cost Model (OECD, 2004) and Cost Benefit Analysis (CBA) (Hertin et al., 2007). 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 of the system (Jacob et al., 2006). These effects might influence sustainable development of specific regions, societal groups or sectors. With this second aspect of IA a link between the objective of better regulation and the European Commission commitment to sustainable development (CEC, 2006) is made (Tabbush et al., 2008; Tscherning et al., 2008).

A number of studies have recently been undertaken to evaluate current impact assessment procedures at national and European level. Most impact assessments focus on the issue of better regulation and policy efficiency, while less effort is spent to the balanced analysis of impacts at all three sustainability dimensions (Jacob et al., 2007). This focus might be explained with preferences of decision making bodies. However, the integrated analysis of sustainability impacts is also hindered by a lack of tools and methods that provide the causal knowledge and linkage between policy intervention and sustainability impacts (Bartolomeo et al., 2004). Sustainability A-test (Van Herwijnen, 2006) and IQ-tools (Böhringer and Löschel, 2006) were two recent European projects that conducted comprehensive inventories of impact assessment tools for a variety of policy fields. It became obvious that most of these tools cover only isolated aspects of impact assessment such as scenario analysis or accounting approaches.

SENSOR, in producing a Sustainability Impact Assessment Toolkit (SIAT), focuses on the ex-ante assessment of unintended policy effects on the three sustainability dimensions for the case of land use. The toolkit was designed to support policy making on land use at European level. The tool aims to be robust and easy to use while being based on scientifically sound and reproducible procedures. A number of methodological challenges were associated with the analytical design. The analyses had to be prospective, build across disciplines, sectors and sustainability dimensions, be spatially explicit and include the valuation of simulated environmental, social and economic effects in terms of sustainability impacts. In essence, three consecutive questions had to be answered (see figure 2): (a) what kind of land use changes would happen as a consequence of policy intervention, (b) where will they happen, and (c) do these changes possibly induce an impact on sustainability pathways of respective regions?

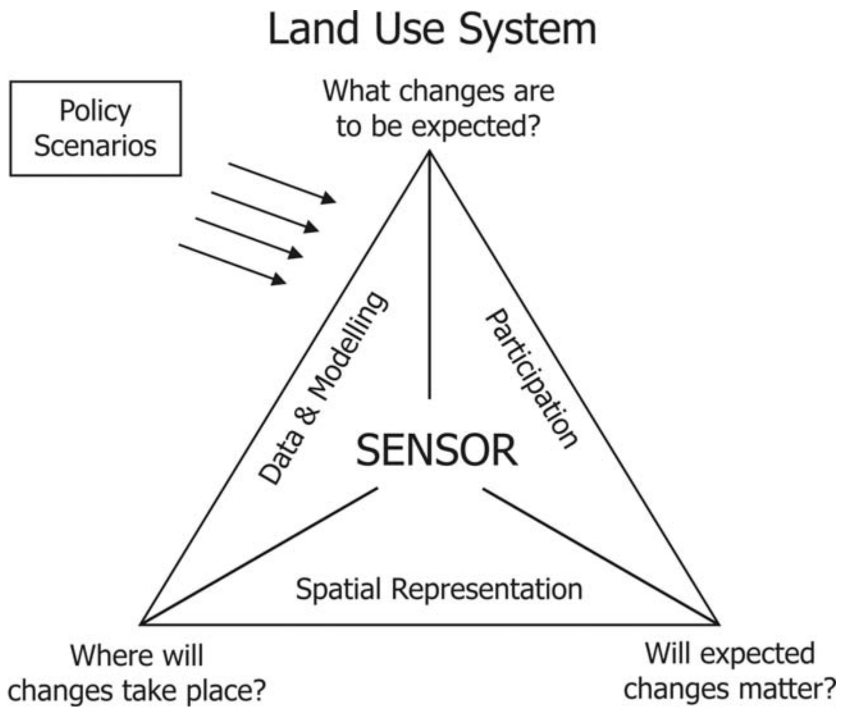

Fig. 2. General questions to be answered with the Impact Assessment in SENSOR

The major challenge for SIAT was to derive a trade-off between full flexibility of policy analysis on the one side, and robust, quick and easy-to-use performance on the other. A comprehensive study of end user requirements and institutional settings at this level preceded the design of SIAT (Thiel and König, 2008). In brief, the analysis revealed that the entire tool should be 'user friendly' with simple, clearly arranged operator panels for end users, whereas the framework of the model had to be 'flexible' (expandable to new policy scenarios). SIAT should be a stand-alone software product without specific hardware or user restrictions. The methodology should be transparent, each methodological step traceable, concise in its illustrations and transparent regarding assessment and data quality. Analysis with SIAT should focus on a broad understanding of cross-cutting trade-offs of land use impacts by a given policy and less on precise accuracy of very specific, detailed policy instruments. To achieve the fast and robust performance, SIAT was realised as a meta-modelling tool, in which models were not directly linked, but in which results of multiple scenario simulations derived from a series of models span a solution space within which future policy options can be analysed (Sieber et al., 2008, Jansson et al., 2008).

4 Analytical design and causal chain concept for impact assessment in SENSOR

The basic idea behind the analytical chain in SENSOR is to (i) link policy options with land use changes, (ii) link land use changes with environmental, social and economic impacts and (iii) provide a valuation framework of these impacts in the light of sustainable development. Seemingly simple, this approach requires complex interdisciplinary cooperation. Most European policies related to land use are economic instruments in the widest sense. Therefore, the link between policy options and land use changes is predominantly an economic issue, but is placed into specific bio-geophysical and socio-cultural settings, different sectors and governance levels. Expertise in these various fields has to be integrated so as to understand land use interrelations with policies. The logical linkage between land use changes and environmental, social and economic impacts is also interdisciplinary. While the understanding of relations between land use changes and environmental impacts is already well advanced (e.g. Ojima et al., 1994), only few studies exist on the direct relation between land use changes and economic and social impacts (Slee, 2007).

In the SENSOR project numerous experts collaborate to analyse the logical cascade of policies – land use changes – sustainability impacts in its full extent. To agree on a logical thread, the DPSIR framework (Smeets and Weterings, 1999) was employed. Developed by the European Environment Agency (EEA) this is a powerful concept to mediate between different disciplinary viewpoints and agree on a common understanding of causal chain relationships between society and environment. It is an advancement of an earlier version developed by the OECD (OECD 2001) and is defined as "The causal framework for describing the interactions between society and the environment adopted by the European Environment Agency: *Driving forces, Pressures, States, Impacts, Responses*" (EEA). The approach has since been adopted in many studies where interaction between human behaviour and environment was at stake (Niemeijer and De Groot, 2006). It is particularly useful when scientific process knowledge has to be translated into knowledge for policy support such as e.g. in the Thematic Strategy for Soil Protection of the European Commission (Van-Camp et al., 2004). The specific strength of the DPSIR concept lies in its adaptability to many different objectives and scales of analysis.

In the SENSOR context, the basic definition of *Drivers*, *Pressures* and *Impacts* is straightforward. Land use change is defined as the *Pressure*. It is affected by two sets of external *Drivers*: (i) those spanning a future socio-economic and technological reference situation and (ii) policy *Drivers* (see section 4.1*)*. The role of *States* is taken by numerous social, economic and environmental parameters that are affected by land use changes and that are meant to provide an estimate of sustainability *Impacts*. This way, the analysis chain departs from a predominantly economic setting (*Drivers*) which is translated into a geophysical setting (land use *Pressures*) and further into an integrated system of the social, economic and environmental settings (sustainability *Impact*s). While the first part of translating drivers into pressures is undertaken with a purely positivist approach of quantitative modelling, the second part of translating pressures into impacts needs to also include normative components in order to embrace the value based character of the sustainability definition (WCED, 1987). This was obtained by expanding the impact component of the DPSIR framework into four consecutive impact steps (Fig. 3). The first step (Impact 1) employs a positivist approach in determining environmental, social and economic state and impact indicators. The second and third steps address the valuation of the indicator changes resulting from step 1. The methods include monetary and non-monetary valuation of indicator changes at regional, in some cases national scale (Impact 2) and assessment of the changes in relation to regional or national standard and threshold values (Impact 3). These two steps are not necessarily consecutive but rather complementary. In the last step (Impact 4) a multifunctionality approach is undertaken to aggregate indicators and their valuations into an integrated assessment of the room for manoeuvre within sustainability choices (Potschin and Haines-Young, 2008). Impact steps two to four are based on normative, partly participatory approaches. This analytical design aims to integrate the top-down data and indicator based modelling with a bottom-up, value driven participatory approach (Fig. 3). The approach to the driving force – pressure relation is further outlined in section 4.1, while the pressure – impact relations are further described in section 4.2.

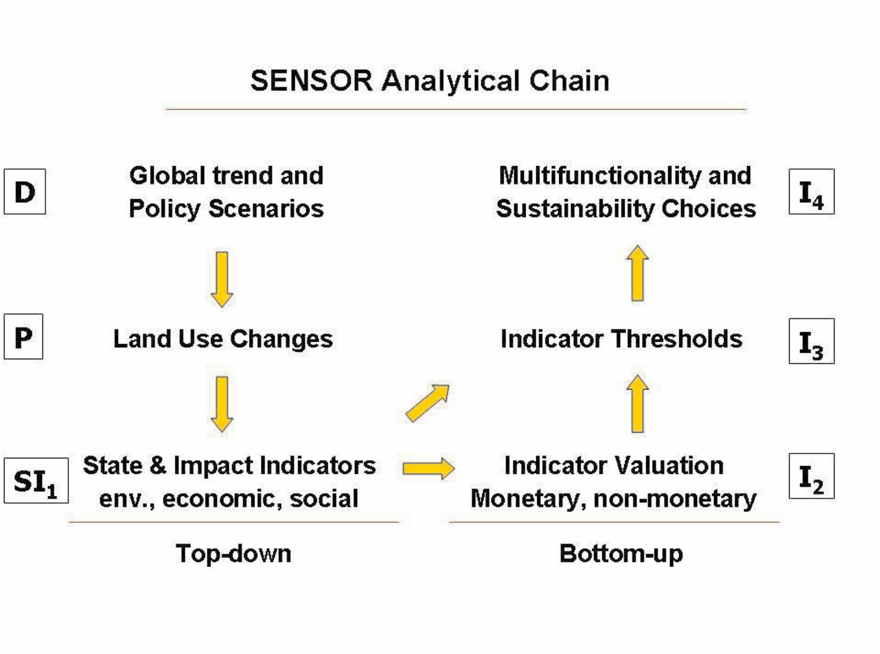

Fig. 3. Simplified analytical scheme of impact assessment in SENSOR integrating top-down modelling with bottom-up participatory approaches and extending on the DPSIR scheme of the EEA. *(D=Drivers, P=Pressures, S=State, I=Impact)*

The component of *Responses* within the DPSIR scheme is not taken up in the analytical design of SENSOR. In its logical setting, the *Response* component would be covered by policy decisions in reaction to simulated impacts. By theory, the policy decision would thus complete the DPSIR cycle. The SIAT tool, which is a translation of the analytical architecture of SENSOR into a decision support system, will help policy makers to comprehend the possible impacts of various scenario based choice options. The decision on the best policy choice itself is therefore exogenous to this tool and not taken up in the analysis scheme (Fig. 3).

4.1 Driving force scenarios for land use changes

The SIAT tool is constructed as a forecasting simulation tool in which future policy options can be analysed as to their possible sustainability impacts in a projection year of 2025. A reference scenario was necessary for such forecasts, presenting land use conditions that would be expected to develop in the absence of any change in policy intervention. To deal with uncertainties in forecasting exercises such as in SENSOR, a number of alternative scenarios are usually outlined that together present a continuous spectrum of possible future situations. Scenario approaches have been widely employed when it came to the need for designing coherent, internally consistent and plausible descriptions of possible futures that were driven by a complexity of interrelated factors (Morita et al., 2001; Alcamo et al., 2005). The development of scenarios was an integral part of prominent studies on environmental change, such as the *OECD Environmental Outlook* (OECD, 2001), the *Millenium Ecosystem Assessment* (MEA, 2003), or the *United Nations Environment Programme GEO-3* (UNEP, 2002) and the *European environment outlook* (EEA, 2005). Most attention was given to the climate change scenarios of the *Intergovernmental Panel on Climate Change* for climate change drivers and impacts (IPCC, 2000).

The general method of designing scenarios depends on the purpose of the study, the complexity of the issue and the available knowledge. It extends from purely probabilistic approaches to target oriented narratives. Probability theories are employed e.g. through stochastic Monte Carlo simulations of probability density functions in cases, where parameter determinants are to be treated in a purely stochastic manner such as in hydrology (see e.g. Samaniego-Eguiguren and Bárdossy, 2006). In contrast, most studies dealing with global economic and policy trends are of deterministic nature. In these cases, scenario storylines are elaborated, in which a set of internally consistent futures is constructed through the generation of logical parameter values for important driving forces (Rounsevell et al., 2006). A third approach to scenario development involves stakeholder visions to design normative scenario narratives. They are employed in cases, where visionary projections and planning strategies are needed (e.g. Volkery and Ribeiro, 2007).

Temporal projections, spatial scale (grain) and extent of analysis are further characteristics of scenario design. In SENSOR, scenario storylines were required as an input for macroeconomic and sector models to simulate future economic reference conditions for land use, on which policy options would impact. The projection year of 2025 was selected to meet decision maker's requirements for medium term perspectives. Driving forces were then identified that affect the economic situations in Europe for this time horizon and that could be simulated with the models under consideration. These were (1) demographic changes in Europe, (2) participation rate in the labour force in Europe, (3), growth of world demand, (4) oil prices at the world market, and (5) expenditure on research and development to simulate technological advance. Climate change related parameters were not considered in this study since current predictions state that climate change will not be of significant direct influence to land use within the time span of ten to twenty years considered in this study (IPCC, 2001). Based on the five drivers chosen, three scenario storylines were then constructed for the year 2025: business as usual, high growth and low growth scenarios (Kuhlman, 2008). These three scenarios were understood as bench marks within a continuum of possible economic futures (Fig. 4).

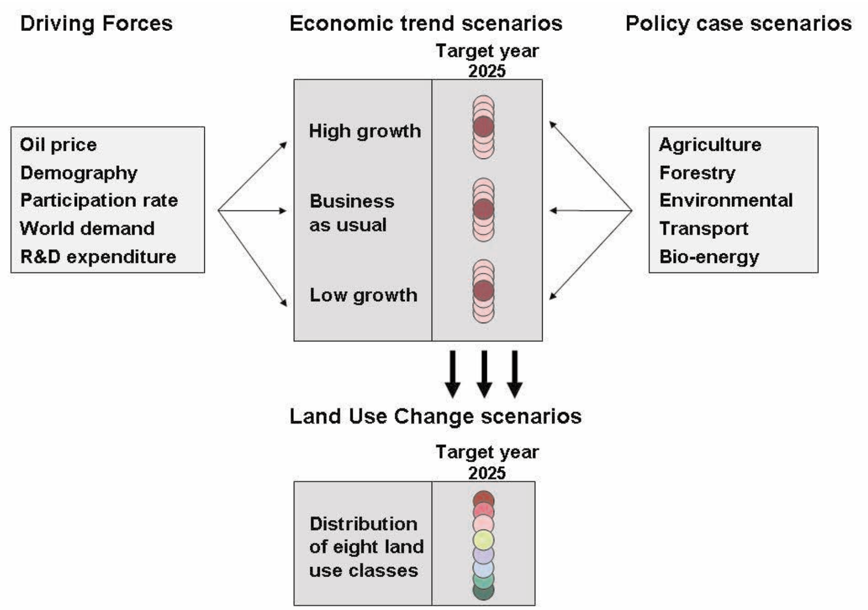

Fig. 4. Scenario design in SENSOR: three reference scenarios for economic trends in the target year of 2025 were constructed (dark purple dots). Policy case scenarios may superimpose on these scenarios (light purple dots). Economic trend scenarios were then translated into land use change scenarios (coloured dots).

Policy scenarios could be analysed against these future trends. The determination of policy scenarios is accommodated by the SIAT tool in the way that users can select among a choice of instruments for environmental, agriculture, forestry and bio-energy policy fields (Sieber et al., 2008). Scenario simulations were realised on the basis of response functions derived by coupling a macroeconomic model (NEMESIS – Fougeyrolla et al.,

2001) with sector models for agriculture (CAPRI – Heckelei and Britz, 2001) and forestry (EFISCEN – Karjalainen et al., 2003). Models for the other land use sectors (tourism, urbanisation, transport and energy infrastructure) were directly built into the macroeconomic model (Jansson et al., 2008). Resulting economic forecasts were then translated into land use simulations by linking sector models with the land use model CLUE-S (Verburg et al., 2002).

4.2 Indicator based assessment of land use changes

Scenario driven land use change simulations derived from CLUE-S model (Verburg et al., 2002) are the starting point for impact assessment in the analysis string of SENSOR. The model displays land use changes at 1 km² grid for eight land use classes: (1) rainfed arable, (2) irrigated arable, (3) biofuel arable, (4) grassland, (5) abandoned agricultural, (6) built-up, (7) forest, (8) semi-natural (Verburg et al., 2008). Special classes with little temporal dynamics (e.g. beaches, glaciers, bare rock, surface waters) are summarised in an extra category. With the subdivision of agricultural land use into five distinct categories (classes 1-5) credit was given to the fact that the highest land use dynamics as well as the most pronounced impacts are related to the agricultural sector (Verburg et al., 2008). Since focus was laid on rural land use in this study, urban land use and related activities (housing, waste disposal) were not explicitly considered.

In the first step of the impact assessment (I_1, Figure 3), an indicator based approach was employed to analyse environmental, social and economic state changes and impacts of scenario assumptions and land use changes. Indicators are widely used in decision support systems to condense and translate scientific knowledge into an information basis for decision support (EEA, 2006). It is therefore essential that the selection of indicators ensures relevancy and sensitivity to the purpose of the decision support system and to the demands of its users. For the SENSOR case, this requirement was met by linking the indicator selection to the list of impact issues that is contained in the official guidelines for Impact Assessment of the European Commission (CEC 2005). The list provides those topics that should be looked at in impact assessment and contains 10-12 impact issues for each of the three sustainability dimensions (see table 1). Each of these impact issues was analysed with respect to its sensitivity against policy induced land use changes. Those being sensitive were considered for the assessment.

Table 1. List of social, environmental and economic impact issues contained in the Guidelines for Impact Assessment of the European Commission (CEC, 2005)

SOCIAL Employment and labour markets; Standards and rights related to job quality; Social inclusion and protection of particular groups; Equality of treatment and opportunities, non-discrimination; Private and family life, personal data; Governance, participation, good administration, access to justice, media and ethics; Public health and safety; Crime, terrorism and security; Access to and effects on social protection, health and educational systems; Tourism pressure; Landscape identity; Migration
ENVIRONMENTAL Air quality; Water quality and resources; Soil quality and resources; The climate; Renewable or non-renewable resources; Biodiversity, flora, fauna and landscapes; Land use; Waste production / generation / recycling; The likelihood or scale of environmental risks; Mobility (transport modes) and the use of energy; The environmental consequences of firms' activities; Animal and plant health, food and feed safety.
ECONOMIC Competitiveness, trade and investment flows; Competition in the internal market; Operating costs and conduct of business; Administrative costs on business; Property rights; Innovation and research; Consumers and households; Specific regions or sectors; Third countries and international relations; Public authorities; The macroeconomic environment.

Based on a comprehensive analysis of existing indicator systems (Frederiksen and Kristensen, 2008) an indicator framework was then constructed that supported the selection of indicators for each of the selected impact issues. Indicator selection criteria were: (1) sensitivity to land use sectors relevant in SENSOR, (2) sensitivity to the reference and policy scenarios, (3) sensitivity in relation to the time frame (2025) and spatial system (Europe at regional, NUTS2/3 scale), (4) data availability and operability. As a result, about 40 indicators were selected such that each of the sensitive impact issues of the EC Impact Assessment Guidelines (CEC 2005) could be described with at least one indicator. To determine the indicator values, indicator functions were constructed for each indicator that reflected the causal relationship between land use change and indicator value. Generally, indicators were quantified at NUTS2/3 scale or with higher (1 km^2) resolution and re-aggregated to NUTS2/3. Deviation occurred for some of the social and economic indicators, where data restrictions only allowed for indicator determination at national level. Qualitative methods for indicator determination were employed in cases, where knowledge and/or data restrictions made quantifications impossible (Farrington et al., 2008).

One difficulty of this approach lays in the fact that in some cases the indicator values were not only affected by land use changes, but also by the driving force and policy scenarios themselves or by related internal sector adaptations (Fig. 5). This was particularly true for some of the social and economic indicators. For example, in the case of "employment", the economic trend scenarios themselves have no doubt a direct impact on employment in rural regions. They also affect consolidations within the analysed sectors, e.g. intensification in agriculture, which also has an impact on employment. Only in a third instance, employment would also be affected by land use changes, e.g. through an increase in bio-energy production on the costs of set-aside land (Fig. 5). Since land use change is the major subject of this project, land use change impact relationships were given preference in the indicator analysis.

The second step of impact assessment (I_2, Fig. 3) was devoted to the valuation of the analysed indicator changes in monetary and non-monetary terms. The monetary valuation was based on an accounting framework for externalities to determine the monetary magnitude of external costs and benefits associated with observed indicator changes (Ortiz et al., 2007). The accounting framework was a simplified version of the Impact Pathway Approach (IPA) used in the European project *Externalities of Energy* (Extern E, 2005). The non-monetary valuation employed internet-based and group valuation methods to reveal stakeholder targets and preferences with respect to land use change impacts (Romano and Ferrini, 2007).

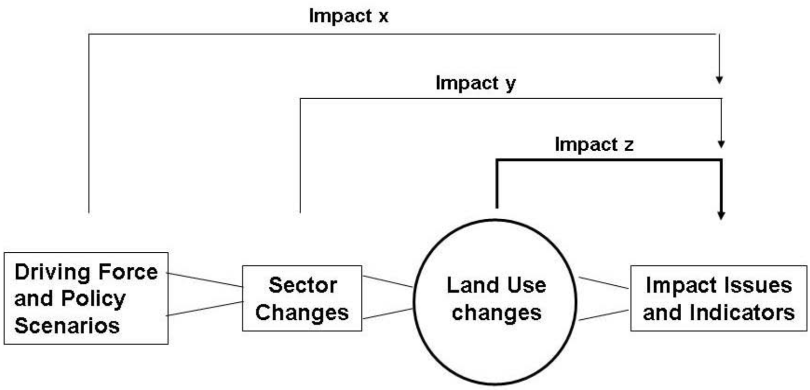

Fig.5. Causal relations between driving forces, sector changes, land use changes and impact issues. SENSOR focused on the relation between land use changes and impact issues (Impact z).

The objective was to cover the question of: "do the simulated changes matter" of Figure 2 in a regional context.

The third step of impact assessment (I_3, Fig. 3) was to confront the analysed changes in impact indicators (step 1) with respective regional and/or national threshold values. The approach was based as far as possible on available, published thresholds and/or standards for respective indicators (Bertrand et al., 2008).

4.3 Multifunctionality assessment and sustainability interpretation

Finally, the fourth step of impact assessment (I_4, Fig. 3) was to consolidate the assessment results into a sustainability interpretation. So far, impact analyses of step 1 to step 3 were concentrated on a series of impact issues of the environmental, social and economic sphere without considering their interweaved sustainability implications. This approach to a separate analysis of the three dimensions of sustainability is often summarised as *Triple Bottom Line* (TBL) (Elkington, 1998). TBL has become standard in many studies related to land use and agriculture impacts, e.g. in the Italian INEA study (Trisorio, 2004) or with the terminology of "People, Planet, Profit" in the EURURALIS study (Klijn et al., 2005).

Attempts to assess sustainability impacts with an integrating approach are only recently emerging (Wiek and Binder, 2005). For the case of land use and landscape development, the concept of multifunctionality has evolved as one key concept to operationalise sustainable development (Wiggering et al. 2006; Cairol et al., 2005). Initially, multifunctionality was a purely economic concept linked to the agricultural sector (Van Huylenbroeck et al., 2007). It was developed to recognise the environmental and social services and non-market outputs in addition to the primary purpose of agriculture in producing food and fibre (Maier and Shobayashi, 2001). By linking the supply based concept of joint multifunctional production to an estimation of social demand for such functions, the concept can be made operational for rural development and policy design (Durand and van Huylenbroek, 2003; Bills and Gross, 2005; Kallas et al., 2007). Links to sustainability assessment can also be made (Barkman et al., 2004; Piorr et al., 2006, Zander et al., 2007). In relation to SENSOR, the drawback of this concept is twofold: (i) it is purely restricted to agriculture, (ii) territorial characteristics and landscape specificities are not considered.

Parallel and independent to the concept of multifunctional agriculture, the concept of landscape and/or ecosystem functions emerged in the area of landscape and ecosystem ecology (e.g., Forman and Godron, 1986; Naveh and Lieberman, 1994). The idea behind this strongly territorially oriented concept is that natural and semi-natural ecosystems provide goods and services to human society that are of ecological, socio-cultural or economic value (Costanza et al., 1997). Here, the terms “functions” and ‘goods and services’ are often used synonymously. The ecosystem function approach has been conceptualised towards the valuation of ecosystem goods and services for the Millennium Ecosystem Assessment (MEA, 2003), in which World’s ecosystems were categorised and valued with respect to their provisioning, regulation, supporting and cultural functions affecting human well being. To date, the MA has been widely acknowledged as an extensive concept for linking environmental processes to human well being in the widest sense (Beck et al., 2006). For the case of cultivated landscapes such as analysed in SENSOR, in which economy driven land use plays a dominant role, the MEA concept is difficult to apply (Jones et al., 2006). This is because (i) it was predominantly developed for natural and semi-natural ecosystems and (ii) it addresses social and economic issues only indirectly as a consequence of environmental changes (de Groot, 2002). A bias towards the environmental dimension is therefore inherent in these approaches (Mander et al., 2007).

In SENSOR, an approach to ‘Land Use Functions’ (LUF) was undertaken that builds upon a combination of the above concepts of multifunctionality and of ecosystem services. It considers three perspectives of multifunctionality (Fig. 6):

- The land use perspective addressing the production side of land use functions.
- The landscape perspective that takes account of the territorial geophysical and socio-cultural capital to provide land use functions.
- The societal perspective that reveals demands and priorities towards land use functions.

The Land Use Functions are defined as those services or functionalities that are produced through land use in its interaction with the geophysical and socio-cultural capital of the landscape. In the SENSOR context, nine LUF were identified (Perez-Soba et al., 2008): ‘Provision of work’, ‘Human health and recreation’, ‘Cultural landscape identity’; ‘Residential and non-land based industries and services’, ‘Land based production and Infrastructure’, ‘Provision of abiotic resources’ (water, soil, air), ‘Support and provision of habitat’ (biodiversity, gene pool) and ‘Maintenance of ecosystem processes’.

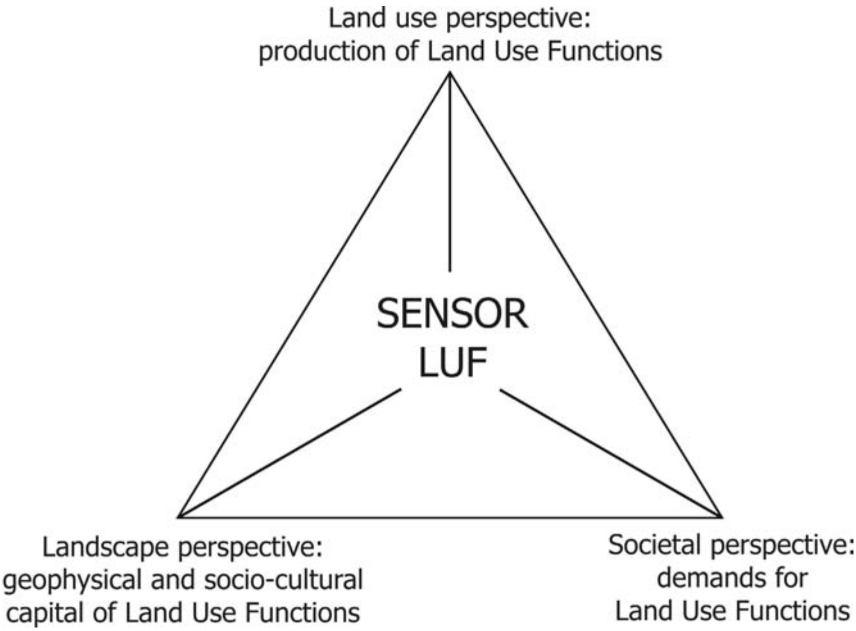

Fig. 6. Approach to Land Use Functions in SENSOR that considers the three perspectives of (1) land use related production, (2) landscape capital, and (3) societal demand to land use functions. *(LUF = Land Use Functions*)

The impact of land use simulations on the performance of these nine LUF was characterised for each region in Europe. This was done with the use of the impact indicators (step 1 above) and based on a Spatial Reference System for European regions (see section 5). It included two steps: (i) quantifying the contribution of each indicator to each LUF and (ii) developing knowledge rules to assess the importance of each LUF for the sustainability of each region. Step two allowed the introduction of a regional specificity into the interpretation of change of pan-European indicators. As a result, the assessments of land use change impacts in SENSOR funnelled into an estimate of changes of the performance of these nine Land Use Functions (Perez-Soba et al., 2008).

When it comes to sustainability assessment, the approach has two important implications: (1) it reduces the confusing complexity of 40 indicators into nine categories of Land Use Functions (see Fig. 7), and (2) it provides an operational basis for stakeholder driven valuation of anticipated changes. This brings us back to the normative notion of sustainability. Adopting sustainable development as a value based concept, in which human needs are the main objective function (WCED 1987), a societal discourse based valuation of sustainability implications is warranted. In displaying the land use policy induced changes of Land Use Functions, alternative policy outcomes can be compared in their implication to these functions simultaneously. Decision makers can then explore the 'room for manoeuvre' in setting targets and limits to these functions creating a 'Sustainability Choice Space' within which sustainable solutions can be achieved (Potschin and Haines-Young, 2008).

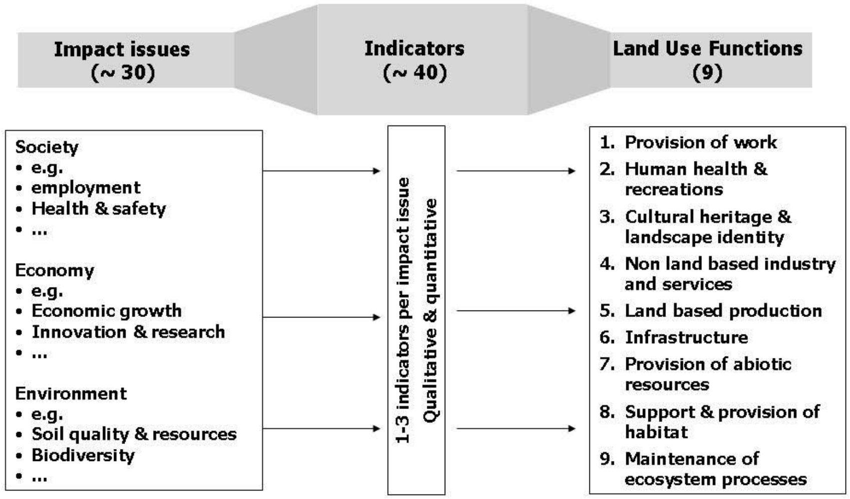

Fig. 7. Relation between impact issues as listed in the EC Impact Assessment Guidelines (Table 1, CEC 2005), indicators and Land Use Functions in SENSOR.

5 Spatial Approach and data management

The mission of SENSOR was to deliver impact assessment for policy making related to land use for the areas of the European Union at regional scale. This implied four important constraints for the spatial and data concept:

1. The area of Europe (EU27) had to be covered and European regions made comparable in their reaction to policy input.
2. Policy relevant, administrative units had to be used for the regional delineation of area boundaries.

3. Particularly the analysis of environmental impacts required higher than regional resolution and context based geophysical delineations of area boundaries.
4. The use of SIAT as a decision support tool required that the vast amount of assessment results were reduced in complexity through area based and thematic aggregation. The result had to be lower than regional resolution.

The first constraint was seemingly simple but had important implications for the analysis. Comparability of results required that all data used for the analysis were harmonised and available across the areas of Europe. To accommodate this, exclusively pan-European existing and quality proved data were used for the assessment. A GIS-based data management system for sustainability impact assessment of land use was developed, which (i) satisfied end-users needs, (ii) could be employed for regional assessments at EU27 scale beyond the lifetime of the project, and (iii) was compatible with major data gathering and data management initiatives such as GEO (http://earthobservations.org) (Hansen et al., 2008). For quality assurance the system is compliant with the INSPIRE principles on architecture, standards and metadata (INSPIRE, 2002).

The second constraint required regional delineation of area boundaries. For Europe, regional area units are hierarchically delineated in the NUTS systems, which is the *Nomenclature of Territorial Units for Statistics* of the European statistical office (Eurostat). Area sizes of the regions depend on the respective national administrative system and vary considerably between countries. Since harmonised areas sizes of regional boundaries were essential particularly for environmental analysis, a spatially homogenised combination of NUTS2 and NUTS3 regions was elaborated. This was done based on an earlier approach performed by the European Environmental Agency (EEA) in the frame of the IRENA project (EEA, 2006) and extended to the 12 new EU member states. The result was a NUTS-X map with 475 units for the area of Europe, which was used as the standard spatial system in SENSOR (Renetzeder et al., 2006).

The third constraint addressed the need for higher than regional spatial resolution for the analysis of environmental impacts of land use changes. This could be realised with the adoption of the land use model CLUE-S in the analysis chain, which operates at 1 km^2 resolution for the area of Europe (Verburg et al., 2002).

The fourth constraint reflected the need to support the thematic aggregation of assessment results into a manageable number of area delineations that reflect the interrelations of socio-cultural, economic and environmental settings on which this project was based. The challenge behind this was to acknowledge the high degree of cultural and natural diversity that exists between European regions (Wascher, 2003) and derive a regional characterisation that equally accounts for bio-geophysical and socio-economic characteristics. The result was a Spatial Regional Reference Framework (SRRF) clustering Europe into 27 regions based on geophysical and socio-economic parameters (Renetzeder et al., 2008).

In summary, the analytical work in SENSOR involved three spatial levels, namely (1) NUTS-X (combination of NUTS2 and NUTS3) as general level, (2) 1 km^2 grid based on the CLUE model for environmental analysis, and (3) a European cluster map with 27 regions integrating geophysical and socio-economic characteristics. For further description of the spatial system, see Renetzeder et al. (2008).

6 Validation and case study testing

To develop decision support tools for policy makers, the analytical chain described above was integrated into the Sustainability Impact Assessment Tool, the SIAT (Sieber et al., 2008). SIAT was realised in the form of a meta-modelling tool in which the modelling cascade and related interrelations of analytical steps was achieved through a series of pre-run global economic trend and policy scenarios. Together they span a solutions space within which SIAT users can define specific policy cases and run the analytical chain (Sieber et al., 2008). In doing so, the models were adapted to the specific requirements in SENSOR and validated separately (Jansson et al., 2008). However, not only did the models have to be tested for validity, but also the analytical concept. Questions had to be answered on whether (1) the most relevant issues regarding land use change and sustainability implications were addressed, (2) the logical linkages between economic trends, policy options, land use changes and sustainability impacts were comprehensible, and (3) the results were plausible. Respective to the analytical design of SENSOR, these three questions entailed a data related component and a value related normative component. To analyse the data related component of the three questions, a series of six case study areas was implemented across Europe. In each of these areas a comprehensive analysis of sustainability issues related to land use and sustainability problems was obtained (Dilly et al., 2008). Extensive data mining and analysis then provided a thorough basis upon which the analytical approaches for indicator determination could be tested. This way, information loss could be determined that arose from the exclusive use of pan-European available data for regional assessment. Regional policy analysis also revealed key sustainability issues as related to land use. This information could be used to check the relevancy of impact issues, indicators and Land Use Functions as analysed in SENSOR (Dilly et al., 2008)

The normative component of validation was based on a participative approach and aimed at identifying societal perspectives regarding land use and sustainability interrelations. In this respect, two groups of stakeholders had to be consulted. The first group was identified as "*problem solvers*" and resembled the possible end users of the final SIAT tool. This group is constituted of policy makers at European Commission level in the widest sense. It also includes research authorities at European level that might assist policy making in applying tools such as SIAT. Several consultancy meetings were arranged throughout the design phase of SIAT in order to include reactions and comments to the SIAT design. This process was also preceded by a comprehensive study on end user requirements and institutional settings related to impact assessment at European level (Thiel and König, 2008). This way, a targeted design of the analytical concept in SENSOR as well as of the operational features of SIAT was aimed to be achieved.

The second group of stakeholders was identified as "*problem owners*". This group represents stakeholders at regional level that are actually affected by sustainability implications of land use changes. Extensive stakeholder sessions were conducted in each of the case study areas to validate the logical thread of SENSOR and identify similarities and differences regarding sustainability issues of land use (Morris et al., 2008). The sessions were organised such that each analytical step in SENSOR was mirrored by stakeholder based estimates on the logic behind and plausibility of results. This way, similarities and differences between expert and data based analysis on the one hand, and stakeholder based analysis on the other hand, could be achieved. This approach complemented the plausibility checking of the SENSOR approach (Morris et al., 2008).

7 Conclusions

SENSOR is a four year project designed to develop *Sustainability Impact Assessment Tools* (SIAT) in relation to land use in European regions. The various disciplinary approaches, analysis scales as well as the complementarity between quantitative modelling and indicator-based analysis on one hand, and qualitative, stakeholder driven approaches on the other, make the project complex. This paper provides an overview of the analytical design of the project. At the time this paper was written, the activities in

SENSOR were ongoing. The conceptual design was elaborated, but some of the results had yet to be substantiated. Emerging results and the actual use of the constructed SIAT tool will prove the validity and robustness of the analytical design described in this chapter.

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Transfer into decision support: The Sustainability Impact Assessment Tool (SIAT)

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Abstract

This paper focuses on the development process and performance of the integrated meta-model Sustainability Impact Assessment Tool (SIAT), whose appropriateness for Sustainability Impact Assessment is finally discussed.

The integrated meta-modelling approach SIAT is the central product of the project SENSOR, which innovates a simultaneous ex-ante policy impact assessment by 45 indicators with a full coverage of EU27. The knowledge-based model SIAT enables end users to assess the effects of land-use relevant EU-policy strategies and evaluate the impacts against sustainability criteria.

The concept of the development process is crucial for the success of SIAT, since problem- and user-orientation can only be ensured by meeting precisely user's requirements. The adequate external involvements of institutions in the design process as well as project-internal knowledge integration are essential keys for success. Latter focuses on quantitative assessments, qualitative knowledge and ensuring a consistent multi-scale interconnectivity.

The novelty of the meta-model approach SIAT consists of the dual approach that a) analyses by 'impact identification' the effects of changes on multifunctional land use and subsequent b) assesses their fulfilment of sustainable tolerance limits through 'sustainability (risk) valuation'. The model framework focuses on cross-sectoral trade offs and side effects of the six sectors agriculture, forestry, energy, transport, nature conversation and tourism. The regionalisation of results is rendered in administrative European regions (NUTS2/3).

The discussion concludes that the integrated meta-model SIAT is a feasible model concept to conduct sustainability impact assessments.

Keywords

Policy Decision Support System, Knowledge-based model, Impact Assessment, Sustainability Assessment, Multifunctionality, Policy Advice, SIAT, Design Process

1 Introduction

The development of SIAT within the SENSOR project aims at supporting decision discussions for sustainable development (Sieber et al. 2006), which contribute to the process of ex-ante sustainability impact assessment (SIA). SIA is an important instrument towards the fulfilment of the European Sustainable Development Strategy (CEC 2001) and is obligatory to be conducted on policy proposals before decisions at European level (EC 2005). The European Commission presented an Impact Assessment process (IA) that consists of 6 steps in the European IA Guidelines (CEC 2005). Within this IA procedure the developed Sustainability Impact Assessment Tool (SIAT) covers step 4 and 5: the analysis of policy options, the assessment of the divergence to defined objectives and the comparison of policy options.

Current operational tools are mostly restricted to precise, but qualitative sectored information on aspects of economic, social or environmental impacts that are mainly designed for ex-post analysis (Bartolomeo et al. 2004). They answer less integrated and comprehensive questions (Tamborra 2002), which causes the strong need for integrated ex-ante impact assessment tools. Thus, SIAT aims at supporting ex-ante sustainability impact assessment towards an integrated perspective of a comprehensive analysis of cross-sectoral effects of policies related to multifunctional land use in European regions.

To achieve this, end user requirements of the European Commission (EC) and others have been surveyed and structured to be able to design the model with desired features that ensure acceptability and high usability.

2 The process of designing SIAT

Policies on land use are highly dynamic and have cross sectoral effects. Understanding the size and impacts of these effects before the policy implementation improves effectiveness of policy creation. For this, the EU-impact assessment steps should be harmonised with the following policy life cycle steps: (1) recognition: determination of the nature and size of a problem, (2) policy formulation: acknowledgement of issues and formulation of measures, (3) solutions: measures are acknowledged and policies evaluated and (4) supervision: policies are implemented and governments enforce and monitor the implementation (Winsemius 1986).

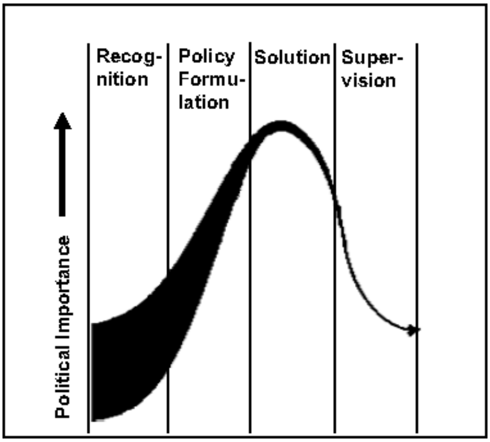

Fig. 1. Policy life cycle (Winsemius 1986)

SIAT provides direct decision support of policy formulation and solution finding within the policy life cycle. Therefore, potential end users are involved during the development of SIAT through evolutionary prototyping. Permanent and iterative end user involvement assures that SIAT approaches end user requirements that are essential for the tool acceptability (McConell 1996).

Three potential user groups have been identified: (1) The end users at the level of the EC as key contractor and decision maker. (2) The joint research institutes of the EU (e.g. JRC) providing decision makers with direct information on model analysis. (3) The numerous consultancies, which are involved in EU-Impact assessments. Although these three potential user groups show a discrepancy regarding their requirements, they will be subsumed under the term “end users” in the following.

The external tool development on end user requirements is described in chapter 2.1. Here from developed internal processes within SENSOR are depicted in chapter 2.2. Chapter 2.3 subsequently focuses on the essential integration of both processes.

2.1 External involvements in design

Beyond the IA guidelines, external involvements have insistent influence on the model design of SIAT. Hence, institutional analyses have been performed both, from literature and as operating experience to take into account main requirements and organisational aspects into the current prototype design.

Since the EC as *external contractor* has immense influence on the model design, different roles, interactions and applied methods between participants have been analysed towards achieving a common SIAT design that ideally meet exactly the EC end users’ requirements of a preferably broad audience (Checkland and Holwell 1999).

Supporting *decision making* limits the scope of the SIAT design process to a specific focus on an end-users’ information needs. For any existing process of decision making the institutional structure plays an important role for the design. SIAT aims at providing relevant information in a manner, which improves the way in which the employees of the European Commission (EC) work together across the different organisational structures of Direction Generals (DGs). In order to meet the goal of an accepted SIAT design the organisation should be analysed with regard to *organisational structure*, *internal processes* and *roles of actors*.

Specific *hierarchies* and the degree of cross-organisational use cause different requirements on the design (Vetschera 1997). Generally, wider user groups and increasing cross-departmental decision spaces lead to an increase of support required for user-friendly handling. Due to abundant cross-sectoral thematic views, the analytical level is broader and focuses rather on comprehensive quick-scan analysis than on high performance of accuracy. The decision level of the potential SIAT user group aims primarily at a hierarchical system that supports decision making within the EU-

Commission at the *same organisational level*. Hence, SIAT provides information which directly guides to the decision solutions (Fredman et al. 1999, Aggarwal and Mirani 1996) at the same organisational level of the EC for cross-cutting analysis.

Different *operational aspects* of common objectives should be considered, as they affect the design of SIAT. Ideally SIAT will be used by the scientific consortium designing the tool and at the same time by externals at the EC level. The SIAT designer have to understand demand-pull design in orientation (Reeve and Petch 1999) and may have to use 'socio-technical' methods like Soft Systems Methodology (Winter et al. 1995) during the development process to characterise and better reflect organisational needs in tool design. Often a good narrative is more engaging and useful than the best science (Checkland and Holwell 1999). Therefore, the SIAT interface and the entire model development itself should try to conform to the *preferred communication systems* of targeted end users.

In summary supporting organisational decision making at the EC level should minimise the risks by (1) establishing linkages with an adequate number of potential end users as catalysers in case of staff rotation and displacements respectively; (2) involving potential end users in the development process earliest possible, but with respect to different development phases of stakeholder involvements. (3) As key for creating awareness collaborative development should further be strengthened in terms of increasing the use of SIAT. (4) Continuity of the iterative process development towards a reliable and confidential relation between respective sharers is an essential success factor.

The major outcome of these considerations resulted in the current 'state-of-the-art'-design of the first SIAT prototype. As a major condition the design should be ideally a mirror of reasonable end user requirements, which are translated to 'internal process design' in chapter 2.2.

2.2 Internal integration processes

The innovative concept of the Sustainability Impact Assessment Tool SIAT is the integrating character of a wide scope of gathered knowledge into one meta-modelling application. This efforts multi-level internal integration processes to be conceptualised and steered in an efficient way. A model is generally regarded as an abstraction of phenomena of the real world, while a meta-model is a further abstraction that is highlighting properties of the model itself (Pidcock 2003).

To make meta-modelling functioning, response and indicator functions describe the behaviour of certain indicators regarding changes of the external circumstances e.g. by a policy (also compare the process towards *response functions*). The knowledge to be integrated differs in its characteristics and reliability, which requires different techniques of knowledge integration. Processing of precise quantitative data is preferable, but in many research fields specific indicators and thresholds are still unconvertible to concise quantitative assessment. Therefore, SIAT uses a three-stage concept that allows a comprehensive integration:

1. An efficient integration of large-sized quantitative data across European regions. In this case response functions are derived from a complex model framework comprising macroeconomic and sectoral models to be integrated into SIAT (see chapter 2.2.1 *Quantitative assessment*).
2. An integration of qualitative knowledge by rules and causal chains between indicators, if quantitative data analysis is not accessible. Knowledge rules are a set of information that describes the principles of a process documented through a causal chain that can be expressed in equations or diagrams (see chapter 2.2.2 *Qualitative assessment*).
3. A holistic approach in order to keep the internal consistency. The need for consistency comprises data reliability on multi-scale level between the participative, sectoral and national up to macroeconomic approaches (see chapter 2.2.3 *Multi-scale consistency*).

2.2.1 Quantitative assessment

At this first phase of internal integration, quantitative information is regarded as the systematic scientific investigation on forecasting land use policies related to quantitative properties and phenomena via a set of connected models. The process of measurement, i.e. achieving outputs as numerical response functions (protocols) have been directly derived from the model framework consisting of macroeconomic and sectoral models.

The SIAT model framework is composed of a series of models interacting in a consistent way. The macroeconomic model NEMESIS translates the five drivers' population growth, demographic structure, labour force participation, world demand, energy prices as well as the expenditures on research and development into certain scenarios for macro-economic variables across land use sectors. Supplied by the NEMESIS results on Gross Domestic Product and regional projections of land prices, the land-use model CLUE-S simulates changes in land use for 1 km² grid cells covering Europe. The models communicate sequentially with five models concerning the different priority sectors, namely CAPRI for the agricultural sector, EFISCEN for the forestry sector, TIM for transport and infrastructure, B&B for the tourism sector and SICK for the urban sector. A set of variables stemming from sector models (e.g. CAPRI), feed their results back to NEMESIS and iterate until convergences on prices and physical land units are obtained. All these simulation models allude to an entirely defined set of model results for each of the pre-defined policies under each baseline assumption. Together, these model outputs form an implicit function, which outlines the cross-sectoral response to policy changes.

In general mathematical terms the needed functions can be expressed in a simple correlation between A, which is the space of possible policies and baseline scenarios, B defined as the space of possible model results and C considered as the space of possible indicator results (Jansson 2006). Because each model results are unique for each policy and baseline scenario, the model framework implicitly defines a function f from A to B. Furthermore, each indicator consists of a rule or equation that is a function g_i from A and B to C, with subscript i indexing the individual indicators. Those assumptions result in

$$f: A \rightarrow B \text{ and } g: A \times B \rightarrow C \tag{1}$$

with f ss the implicit function jointly defined by the simulation models and $g = (g_1, g_2, \dots, g_i, \dots, g_n)$, where n is the dimension of C (the number of indicators) is called the vector of *indicator functions*. The model user requires the indicator results as a function of policy, which can be computed as $h = g \circ f$. The symbol "$\circ$" is the composition operator, so that for some policy x in A, the result of $g(x, f(x))$ is preferred. Intermediate results of B are important on land use change, so SIAT is looking at $h: A \rightarrow C$).

Due to the complexity of the function h, SIAT approximates $h = g \circ f$ with some functions η. Letting "$\approx$" mean "is an approximation to", the following two approximations are considered: either $\eta = \phi \approx g \circ f$, meaning that the whole composite function is approximated, or $\eta = g \circ \phi$ with $\phi \approx f$, i.e. only the implicit function f is approximated. The vector of functions ϕ is called "response functions". This means each indicator can be modelled either by a direct link between the policy variable and indicator variable, or in two steps using model results like land use change as an intermediary.

For each model result variable, the entire modelling chain is approximated by a general flexible form with a small set of parameters. Only a limited number of simulation experiments form the base for the estimation of the response function, and thus a second or third degree polynomial is suffice in most cases to hit the few observation points very closely.

Summarising, each of the quantitative sustainability indicators consists of a direct model output or a mini-model, which is fed by land use change and/ or another models' output. As a result, a reliable set of numerical "response protocols" is provided at regional level.

2.2.2 Qualitative assessment

Unlike precise quantitative knowledge integration, qualitative information depends on logical reasoning of cause and effect behind diverse aspects of behaviour. Qualitative knowledge develops overall understanding of structures and their systemic behaviour, if the necessary quantitative information is not available. This requires constructing on causal cause-effect chains between policies and indicators, and ultimately the response and indicator functions associated (see figure 2).

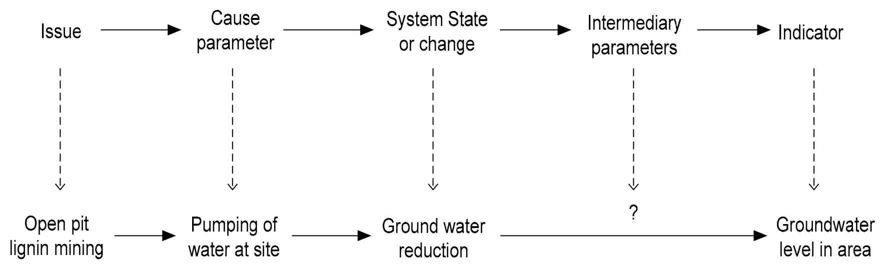

Fig. 2. Ground water-causal chain translated into an indicator

In view of the fact that for many cases (particular social science) tangible data is often lacking, it is not possible to define response functions for qualitative information properly based on scientific literature review. For those cases, the Delphi-Method has been applied.

The Delphi method is a systematic and interactive evaluation method to generate scenarios and make prediction for difficult problems and relies upon independent inputs of selected experts within the consortium (Adler and Ziglio 1996). This is done in accordance to group-modelling techniques developed by Vennix (1996). Expert opinions and experience is used to focus on an agreement on certain behaviour of response functions.

The Delphi solution has been specifically developed for SIAT and enables a conversion of conceptual issues through causal chains into a functional variable. Response functions are made up by a set of parameters derived out of causal chains. The causal chains are made out of several input parameters that are indirectly influencing the functional relationship that determines the intensity of the indicated value.

Each variable joined in a causal chain carries different type of intensities upon the goal indicated value. These different intensities summed together may amplify the indicated effect (the indicated value) in such a way that it is possible to classify the sensitivity of the effect into weak, intermediate or strong effect (see figure 3). This standardisation of response functions enables experts where no empirical data exists to endow into three part input choices.

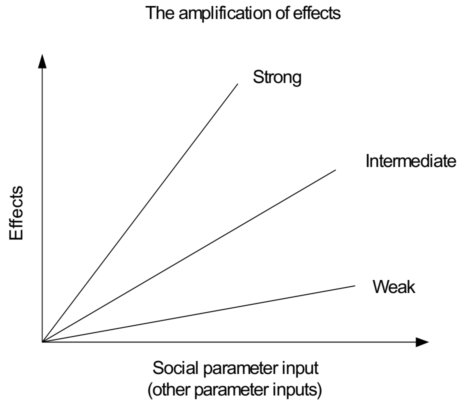

Fig. 3. Three-part input choice of effects on response functions (Haraldsson 2007)

A response can be either negative or positive. SIAT always deals with parameters that may demonstrate an 'indicative' value towards describing the system state. Depending on the desired performance to be measured in the system, the parameters may have different useful indicative values. Parameters can demonstrate low or no usefulness, but they are at the same time important process parameters in the causal chain. Process parameters may become valuable as an indicator, if the focus of the purpose changes.

In summary, during the work process of developing the response functions for the indicators, a construction group was formed that consists of experts from the different knowledge areas. The experts enable an iterative process by subjecting the different proposal to test and rework until a final SIAT proposal was developed (see figure 4).

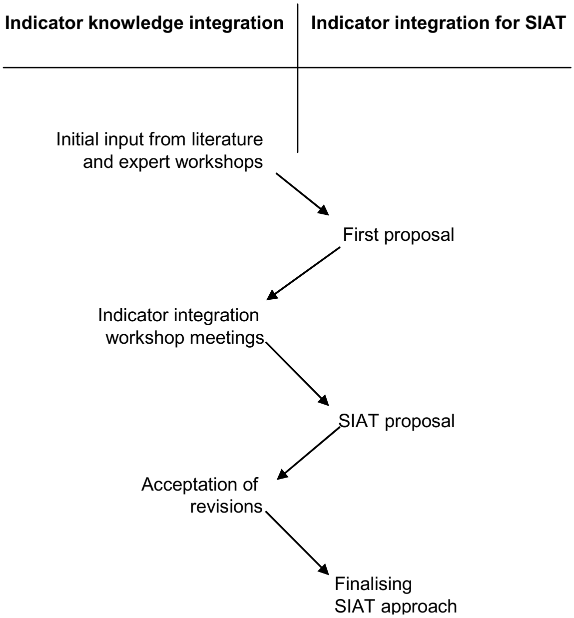

Fig. 4: Methodology for the workflow of indicator integration into causal chains.

2.2.3 Multi-scale consistency

Additionally to integrating quantitative as well as qualitative knowledge into SIAT, the third phase of the integration process deals with the overall consistency of structure and data. An increasing body of literature has developed on the quantification of the sustainability across different sectors. Usually, this literature promotes the idea of monitoring a range of sustainability indicators recognising that sustainability cannot be condensed into a single definition (Pannell and Glenn 2000). Most of these indicators are strongly ecological in focus and very detailed, or they are policy oriented and developed at aggregate, sector or country level. So, indicators are developed that differ greatly in information content and condensation of this information. Scientists are most interested in uncondensed data that can be analysed statistically. Policymakers and the public in general can be assumed to prefer condensed data related to policy objectives and free of redundancy (Pacini et al. 2003).

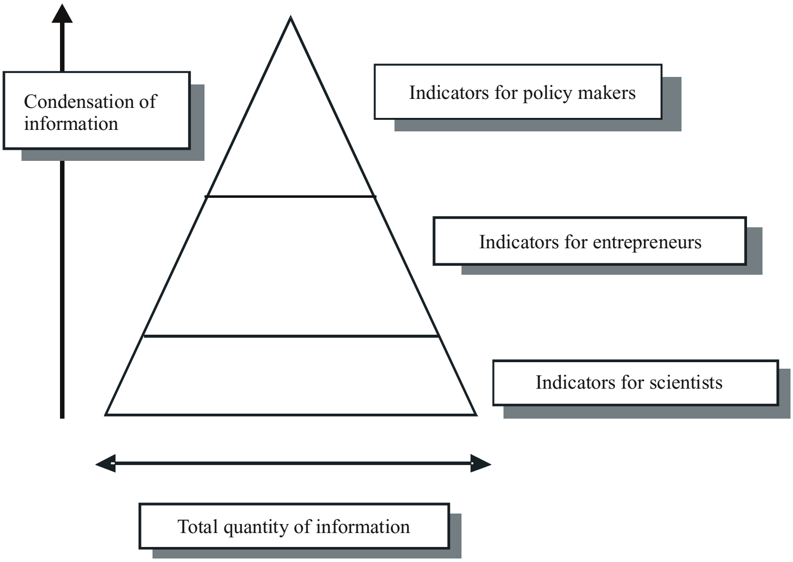

Fig.5. Relationships between indicators (Braat 1991)

Generic end user requirements

What previously stated poses some issues of communicability between researchers, whose main aim is to model reality in the most scientifically consistent way, and policy makers, who desire both using the models to predict the effects of a given policy option and getting a transparent insight on how the models behave under different scenarios.

The SIAT is a problem- and user-oriented tool and, as such, needs its modelling framework to be even more transparent and linked to the users' perspectives. From an end user perspective, SIAT requirements include:

- Transparency of processing methods of indicators
- Effectiveness of indicator results', presentation tools in terms of condensation and non-redundancy of information
- Possibility of aggregation of indicators on different spatial scales, sustainability themes and land use functions in order to get quick scan answers at different levels
- Holistic approach
- Possibility of performing sensitivity analyses of main parameters

There are many methods of presentation of indicators that can be used: text, tables, graphs (including indicator diamonds, also known as spider or radar diagrams, or amoeba-type graphs), and maps are some examples. In addition, it can be advantageous for the analysis to use baseline values, thresholds, targets and other comparators. While textual and numerical presentations have the advantage to enable better quality control as they supply more detailed information, graphs are per definition visual tools and may, as such, be more communicative than a table, although disregarding some information (Segnestam 2002).

Within the framework of numerical presentation there are different ways to present results, depending on the level of aggregation of indicators. Using composite indicators (or indexes) allows for an overview of sustainability, obtaining clear messages for end-users and condensing a critical mass of information while avoiding redundancies (Segnestam 2002). However, aggregated indicators are often said to bring forward a reductionistic vision (Hoag et al. 2002), while presenting results of sustainability assessment by a set of indicators can assure higher levels of transparency and is more recommendable from a holistic viewpoint.

Graphs such as spider diagrams and trade-off curves are more communicative compared to numerical presentation, although they present information in a less detailed way. Spider diagrams are very effective and are often used in reporting to different stakeholders (see e.g., Vereijken 1999, Nicholls et al. 2004).

Antle, Capalbo, and Crissman (1998) argue that plotting economic indicators against environmental indicators for alternative production systems is a preferred method for presenting information to policymakers. The trade-offs between the various dimensions of sustainability are transparent and decision makers can place alternative weights on those dimensions in determining the appropriate balance between the health of the environment and the economy (Weersink et al. 2002). Similarly, Pannell (1997) observed that simple approaches to sensitivity analysis, such as the trade-off curve approach, may actually be the absolute best method for the purpose of practical decision making.

Another tool for results' presentation are maps. They can be built either with the help of remote sensing or with geographical information systems (GIS). The main advantage of maps is probably that they allow several indicators to be analysed at the same time in an illustrative and easily comprehended way, on different spatial scales and considering simultaneously different dimensions of sustainability (Segnestam 2002). However, two important drawbacks of using GIS maps are that transparency of data processing methods is not easily achieved and cause-effect chains cannot be displayed.

Requirements of EC impact assessment (IA) guidelines

Primary SIAT end users are EC desk officers who are preparing and accompanying decision making processes. EC IA guidelines (EC 2005) give indications on a number of issues regarding evaluation of policy options, including comparing options. Four major IA requirements to compare options are:

- Weigh-up the positive and negative impacts for each option
- Where feasible, display aggregated and disaggregated results
- Present comparisons between options by area of impact (economic, environmental, social)
- Identify, where possible and appropriate, a preferred option

As a first step, the impacts of each option should be summarised by area of impact (economic, environmental, social). In this summary, the impacts should not be aggregated; negative and positive impacts should be stated next to each other. In some cases, it may be possible to assess net impacts per area of impact and potentially to provide an assessment of the overall net impact of each option. This can be done by multi-criteria analysis, cost-benefit analysis and cost-effectiveness analysis, each of them showing advantages and disadvantages relevant to the specific object to be evaluated. The final evaluation of policy options is enforced against a number of criteria, whose effectiveness, efficiency and consistency are generic and apply to all proposals subject to IA (EC 2005). While measurement of effectiveness and efficiency can be directly calculated by the SIAT model starting from simulation settings and corresponding indicator response functions, the consistency criterion requires for, where feasible, aggregated results by area of impact (economic, environmental, social). In Table 1 one way to present a summary comparison of a number of policy options is reported.

Table 1. Example of summary comparison between policy options (CEC 2005)

Policy option	Effectiveness	Efficiency	Consistency
Option A	Achievement of policy objectives ‘A’, and ‘B’	‘X’ resources needed to achieve level of impacts ‘y’	Good balance of positive and negative (un)intended/(in)direct impacts in economic, social and environmental matters
Option B	Achievement of policy objective ‘A’ only	’2X’ resources needed to achieve level of impacts ‘y’	Positive economic impacts; negative unintended impacts on the environment, namely …
Option C	…	…	…

The EC IA guidelines give indications also on the final choice to be made among the selected (effective, efficient, consistent) policy options. It is specified that the final choice is always left to the College of Commissioners; the decision support system must only provide the Commissioners with a rank of options made according a number of criteria. “However, as an important aid to decision-making, the results and the alternative options considered – in all cases – need to be presented in a transparent and understandable way to provide the basis for a political discussion on the relative advantages and disadvantages of the relevant options. This allows political decision-makers to examine the trade-offs between affected groups and/or between the impacts on the social, economic and environmental dimensions” (CEC 2005).

What above reported means that SIAT should include some method to rank the options by groups and/or by sustainability dimension, and this implies the possibility to aggregate indicators and supply end-users with results to address trade-offs.

SIAT internal consistency requirements

Internal consistency SIAT requirements related to aggregation and presentation of indicators’ results include:

- Conceptual and data consistency between impact assessment (IA) issues, Land Use Functions (LUFs) and relevant indicators
- Consistency between the macroeconomic, top-down approach and the regional, participative, bottom-up approach

SIAT has been developed to meet end user and EC IA guidelines’ requirements. Besides, the modelling architecture has to be consistent with given principles and calculation needs indirectly connected with the above-mentioned requirements.

As for the consistency between the macroeconomic and the regional approaches within the framework of SIAT, one major point to be taken into account is the need to guarantee a pan-European validity for a tool used by EU desk-officers while respecting the extreme diversity of EU regions. This poses requirements of model validity on different spatial scales, as well as identifying and including region-specific survey methods to refine the analysis of sustainability such as, for example, participatory analyses to weight and rank policy options. A multi-scale approach calls also for requirements and corresponding procedures to tackle the proportionality criterion, e.g. if and when applying region-specific detailed analyses in proportion to the actual extent of the policy option under valuation.

3 Result: The integrated concept of SIAT

Based on the described external and internal processes the ex-ante Sustainability Impact Assessment Tool (SIAT) has been developed to meet the needs of analysts and policy makers at the European level (Verweij et al. 2006). SIAT enables decision makers to assess the effects of land-use-related policies by means of (1) European policy impact analyses and (2) regional threshold assessments and target identification for sustainability valuation.

3.1 Methodology and features of SIAT

The meta-model SIAT is defined as a transparent quick scan approach that offers a large number and high level of applied "real" policy options. SIAT is scenario driven and considers global economic, demographic and policy trends. It provides multidimensional perspectives for long-term land use changes for the target year of 2025 and focuses mainly on investigating cross-sectoral trade-offs on sustainability criteria at a regionalised level of the EU. The scenario results are presented in administrative schematisation (NUTS 2/3) with coverage of all 27 Member States plus four associated countries. Specific sensitive regions are complementarily analysed and case study analysis validate scenario results.

Policy simulations consider changes between the land use-related sectors agriculture, forestry, energy, transport, tourism and nature protection and range from non-monetary policy instruments (e.g. soil directive) to monetary instruments as taxes and subsidies (e.g. subsidies for renewable energies). For each of the policy options the impacts and risks are assessed by means of 45 sustainability indicators.

The theoretical concept of multifunctionality has been developed as one key approach to implement sustainable development in the area of agriculture and land use (Cairol et al. 2005). In this regard multifunctional land use is intended to integrate social, economic, and environmental effects simultaneously and interactively within the set of all observed land use actions. Based on the multifunctionality concept, SIAT aims at synthesising all three sustainability dimensions. The multi-functionality approach assesses analytically the (1) impacts of the cross-sectoral effects of introduced policy variables. At a second level the (2) indicator results are compared with introduced critical limits as scientific-based thresholds and policy-driven targets (tolerance limits). Both are computed for clustered problem regions that reflect the same biophysical and socio-economic site-conditions as similar multi-criteria profiles.

The innovation of SIAT is the integration of the six sectors by deriving response functions from integrated macroeconomic and sectoral models. For each policy case a separate derivation of sets of response functions is assessed. At national level the macro model NEMISIS (Kouvaritakis 2004) safeguards the statistic accounting frame. The sectoral models CAPRI (Britz et al. 2003) and EFISCEN (Lindner et al. 2002) determine intra-sectoral coherences in agriculture and forestry (see chapter 2.2.1). By using this concept, SIAT translates relations from (1) introduced policies to land use claims. At a second stage (2) changes on land use are translated to changes on impact indicators (see figure 6).

For those impact indicators, which are not directly derived from the modelling approach, specifically applied ‘rules of thumb’ ensure the implementation into SIAT. These knowledge rules are generalisations of complex processes applicable in specific circumstances. Rules of thumb are expressed in relative small calculation methods like response functions, or decision trees (see chapter 2.2.2). As a result the model response time is minimised. In order to assure connecting the knowledge rules simultaneously, the SIAT applies the Open Modelling Interface (OpenMI) standard for linking calculation components (Gijsbers et al. 2002). The use of this standard increases efficiency and minimises the risk of system development (Wal et al. 2003).

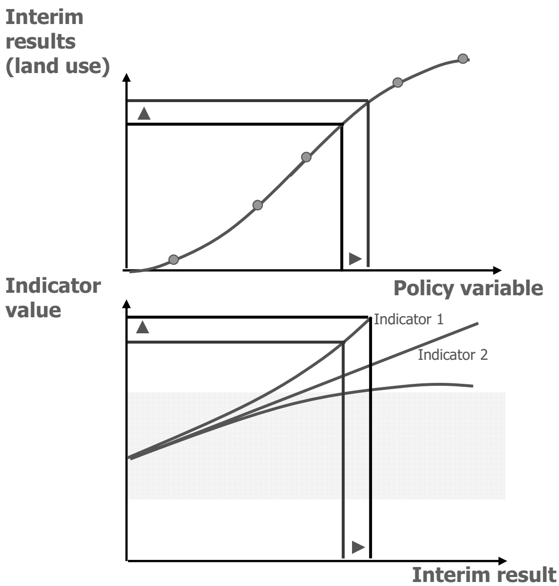

Fig. 6. Dual approach of policy and indicator functions in SIAT

An additional challenge is to create a truly stakeholder driven process of developing the SIAT. Since researchers initiate the solution searching process, the risk of overestimating topics as problem definition, solution space, and technical means has to be minimised through involving local stakeholders for result validation. The increasing need to involve broader groups of stakeholders, and their increasing interest to be involved in policy requires an unbiased start (Wien et al. 2005). In this regard, SIAT works at the level of sensitive regions, cases study regions and test regions.

The SIAT follows two main modelling-related principles: transparency and back tracing. Transparency of knowledge is guaranteed by (1) offering fact sheets for all implicit knowledge and (2) explicit back tracing of the knowledge used during calculations. Back tracing shows how and with which assumptions the calculations for a specific region within the EU were carried out, including information on the uncertainty bounds.
Specific fact sheets consist of (1) opening pages of each category that summarise the specific topic and serve as an introduction, (2) sub-categories as summary reports that emanate from different sources as deliverable reports, existent other reports and modules' contributions, (3) fact sheets on specific qualitative indicators giving region-explicit information on the result, knowledge rule and inter-linkage on causal chains and (4) summarising the assumptions for definition the reference and policy scenarios.

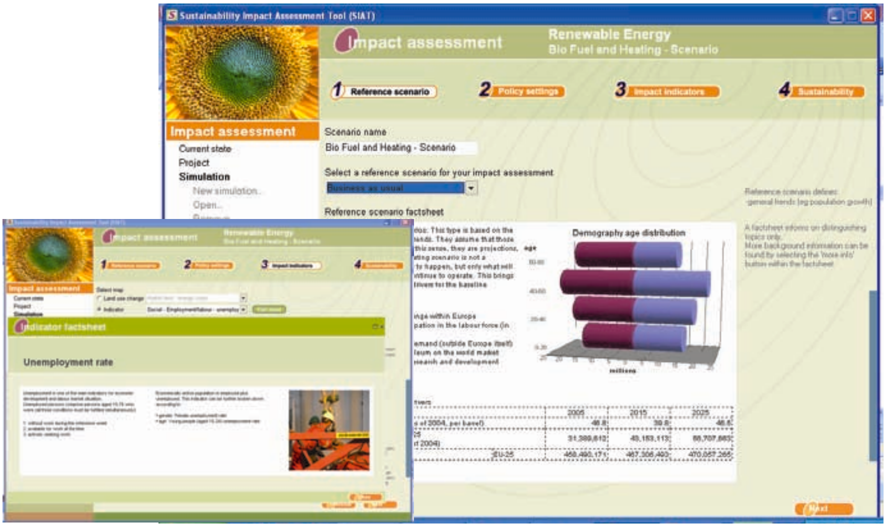

Fig. 7. Two exemplary fact sheet categories (a) embedded (large screen shot) and (b) new frame

3.2 Applying Policy Simulations

The SIAT lays emphasis on simulating future scenarios. As it forms the model core, the *procedure* on how to solve policy scenarios has been essential part of the first prototype. A complete scenario comprises five steps: defining the (1) reference scenario, (2) policy settings for the scenario definition, (3) analysing results as impact indicators, (4) valuating sustainability risks and last but not least aggregating indicators to (5) land use functions.

The first step (1) defines the macroeconomic reference scenario to compare results of different policy simulations. The results of these reference scenarios are projected to the target year 2025 to be able to identify the impact of the policy scenario results. The three reference scenarios business as usual, high-growth and low-growth assume positive and negative anticipated trends of the incorporated land use drivers, oil price, R&D-expenditures, technological developments, demographic changes and global economic changes. Step number (2) selects policy measures and intensities for policy scenario definition. The user can define the intensity of policy simulations within pre-cooked solution spaces. Step number (3) investigates the impact results of the introduced policy variable that is presented in interactive maps, tables and graphs. Photorealistic visualisation underlines the result expressions. Step number four (4) is the sustainability valuations of the conducted impact assessment which is based on region-specific tolerance limits. The simulation that has been defined and analysed in these steps is based on single indicators. (5) Step number five takes groups of indicators in a more balanced analysis into account and aggregates them through specifically developed scoring systems. This step developed a concept of Land Use Functions (LUF) that indicates in amoebae diagrams the level of goods and services at regional level. At this level multiple scenario results can be compared among each other. All nine LUFs are part of the scenario analysis component in SIAT: ‘Provision of work’, ‘Human health and recreation’, ‘Cultural landscape identity’, ‘Residential and non-land based industries and services’, ‘Land based production and Infrastructure’, ‘Provision of abiotic resources’, ‘Support and provision of habitat’ and ‘Maintenance of ecosystem processes’ (Perez-Soba et al. 2008).

4 Conclusions

The important aspects discussed in this article concern the process of developing the design of model-based DSS ‘Sustainability Impact Assessment Tool' (SIAT). The research question emphasised the transfer of end user requirements into methodological advancements, which are integrated into the SIAT meta-model for discussion support. Concluding findings are

On institutions:

- Understanding the model development process helps to steer the model design in order to assure success in terms of acceptance, utility and high degree of utilisation.
- Knowing the institution regarding its organisational structure is an empiric key for efficient result-oriented end user collaboration on specific requirements of integrated impact assessment models.

On the meta-modelling approach:

- SIAT is a meta-model that consists of response protocols. 'Pre-cooked' policy simulations allow re-using calculations within given solution spaces. Thus the model response time is minimised for quick-scan policy analysis.
- The meta-model concept causes specific needs for knowledge integration by means of non-standard technical solution finding. The combination of qualitative and quantitative integration techniques allows covering a maximal number of methodologically diverse indicators.
- Most quantitative response functions are derived by a model framework using one macro-economic and 5 sector (sub-) models. Qualitative indicators as knowledge rules ('rules of thumb') are complementarily implemented to close the methodological gap of (mostly) social indicators.
- Transparency and traceability is ensured by fact sheets and detailed storylines. Assumptions and provided methodologies are described and visible at all levels of calculations and result illustrations.
- Assessing the quality of results is key for reliability. Four criteria on indicators categorise the state of the art on indicator calculation methods: (1) process knowledge, (2) explicitness of the indicator, (3) data availability and (4) reliability of up- and downscaling effects.
- Land use functions indicate the level of goods and services at regional level and contain aggregated specifically scored single indicators, which define a 'sustainability choice space' for allowable policy impacts.

As a present overall evaluation it can be concluded, that integrated meta-modelling is a feasible concept to conduct sustainability impact assessments, but on the successful acceptance the end user will have to decide.

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Part II

Scenario modelling of land use changes

Scenarios: Driving forces and policies

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Abstract

Modelling the impact of policies is possible only if these policies themselves are defined to some extent. Therefore, potential policies affecting multifunctional land use are grouped into policy cases around a number of central themes. However, a counterfactual is needed in order to know what the situation in the target year would be in the absence of policy change. Several approaches to designing scenarios for this counterfactual are discussed, and the chosen approach is elaborated into a description of baseline scenarios to be used in the project.

Keywords

scenario, driving force, population projections, macro-economic projections, bio-energy

1 Introduction

A scenario can be defined as a description of an assumed future state of affairs. As such, scenarios are central to the SENSOR approach: it is only by constructing images of the future that we can assess impacts on sustainability. When we are assessing the impact of policies, we need two different kinds of scenarios: those showing the situation where the policy is implemented, and those where it is not – i.e. the counterfactual. It is by comparing the two that we can measure what difference the policy is likely to make. We shall call these two types policy scenarios and baseline scenarios, respectively.

Baseline scenarios can be built by making a number of assumptions about the future and then entering these into a model, or, in the case of SENSOR, a battery of models. These assumptions cover factors which are exogenous to the models: they contain information which the models themselves cannot calculate. The assumptions must be consistent with one another, in order that our image of the future may, if nothing else, at least be valid. To achieve such consistency we combine them into storylines. The next section describes the approach used to construct such storylines. This is followed by the storylines themselves, i.e. our assumptions concerning the future as it would happen without change in policies.

Storylines for *policy scenarios* should, according to SENSOR's goals, be constructed by the users of the SIAT toolbox themselves. It is desirable that they have maximum freedom in choosing the policy options they might wish to evaluate. This presents SENSOR with a dilemma, because any policy option would consist of settings on policy variables included in the models. A new variable conceived by a policy-maker cannot be calculated by SIAT: it has to be built into the tool by the model experts, but it will not be available to the end user until this is done. Therefore, the standard version of SIAT which will be the end product of SENSOR can present only a limited number of policy scenarios; but it is SENSOR's job to make the coverage of different issues as wide as possible. Therefore, it has been decided to construct a number of *policy cases*: sets of policies around issues that are important in multifunctional land use – and in the six sectors with which the project is particularly concerned. Section 4 describes the approach used in building these policy cases and lists them. Section 5 presents the storyline for the first policy case which has already been worked out in detail.

2 What are baseline scenarios?

Several different approaches to the problem of constructing scenarios are possible. We shall here distinguish only four of them:

- *Extrapolating scenarios,* based on the extrapolation of existing trends. They assume that those trends will not change. An extrapolating scenario is not intended as a statement of what is likely to happen, but merely what will happen if recent trends continue to operate.

- *Expert judgment:* rather than assuming a simple continuation of past trends, in this approach experts are consulted for each driving force on the most likely developments. These judgments are used to tweak the trend figures. Although an adaptation of the previous method, its objective is fundamentally different as the expert-judgment approach attempts to describe a *likely* future rather than merely a *possible* one.
- *Inclusive approaches:* Here a set of possible worlds is constructed, in the hope of capturing a range within which the 'real' future will be contained. Commonly, one or more dimensions are defined along which the future may vary, leading to a multi-dimensional space. The size of this space is limited by the assumed likelihood of variation in the main parameters. One may say that this method results in a set of projections which together form a forecast. This approach has been applied by the Intergovernmental Panel on Climate Change (IPCC 2001, 2005), and is popular in scenario studies in the Netherlands (e.g. EURURALIS 2007).
- *Imaginative approaches:* all of the above methods (except, to some extent, the expert-judgment one) recognise that the future is unknowable. However, the imaginative approach carries that insight furthest. Rather than making assumptions about what is likely to happen, it asks people to imagine things which *might* come to pass. Around these imagined but possible events, a set of consequences is constructed through modelling. This is the approach used in the PRELUDE project implemented by the European Environment Agency (EEA 2005).

Each of these approaches has its advantages and disadvantages, and which one is the most suitable depends on the purpose for which the scenarios are constructed (IPCC 2005). The imaginative approach, for instance, is useful if one wants to design solutions to problems that *might* happen, but not if one wishes to know what the future is *likely* to bring. The inclusive approach can answer that, but there is a trade-off here in the number of scenarios to be considered: the more you construct and the wider the range between them, the bigger the chance that one of them will come true; but also, the less interesting your forecasts become. For instance, the IPCC has actually built 41 of them (IPCC 2001). The inclusive method is most appropriate when the purpose is to explore the spectrum of likely futures within which policies may be formulated – rather than what the impact of a given policy will be.

A major advantage of the extrapolating and expert-judgment approaches is that they provide, in principle, a single point of reference. This is important when one wants to know the impact of a policy: one does not need to know the future as such, but only what difference the given policy would make. It was decided that either of them, on this ground, would be suitable

for SENSOR, but which one is to be preferred? The extrapolation method makes no pronouncement concerning the likelihood of the projected situation actually coming to pass. In a way, it provides a dynamic view of the present rather than an improvable view of the future. This makes it attractive to scientists because of its rigour and to those policymakers who recognise that, while claiming to deal with the future, they are really working in the present (assisted, with luck, by some knowledge of the past). The expert-judgment approach is more ambitious in that it believes we *can* know something about the future. Where that belief is justified, it will be of course an advantage if such judgment can inform our scenarios. What the outcome may lose in clarity and rigour it may gain in plausibility.
The problem of choice between these two approaches can be solved by looking at the drivers, the exogenous variables on which assumptions need to be made, and which we shall discuss below. We will have different levels of confidence concerning our understanding of future trends. For some experts are fairly confident on what is likely to happen, for others opinions vary more widely. We may thus opt for a combination of the extrapolating and the expert-judgment approach: where we have think we know what is likely to happen we use the latter, where not the former.
However, there remains one problem. What if the impact of a policy depends very much on the actual situation in the future? In order to answer that question it would make sense to produce, in addition to the main scenario, a sensitivity analysis. This could take the form of upper-bound and lower-bound values for the drivers. The package of values should be chosen so as to arrive at coherent upper- and lower-bound scenarios. Thus, we construct three baseline scenarios: a reference scenario, which is largely business-as-usual but with modifications based on expert judgment where we consider this to be appropriate and two contrasting scenarios for the high- and low-growth options.

3 Drivers

Now we must turn to the drivers, the exogenous variables for which we set values in a scenario. The term has been popularised by the DPSIR approach (EEA 1999), which conceptualises a causal sequence of drivers, pressures, state, impact and response. In that scheme, a driver is a prime mover, a force which is not caused by something else. In reality it always is, of course, but in the model we accept it as given. We do, however, need to recognise that drivers can be causally related to each other. These relations are expressed in our storylines.

Furthermore, a driving force must itself be subject to change; otherwise it is not a force and cannot drive anything. A static condition by definition cannot cause a process of change. Factors such as soil type or topography cannot be drivers: they are constraints which could limit the scope of actions – just like a tree along the road cannot be the cause of a car hitting it. As in the previous point, 'static' here is an abstraction – nothing is ever static. When we consider a certain factor as static, we mean that within the time span we examine, the changes in it are so small as to be irrelevant. Static factors have a place in our analysis, but not as drivers.

Thirdly, we propose that the driving force is always a human activity. This is because in SENSOR we are dealing with the interaction between humans and their biophysical environment. Autonomous changes in that environment are mostly either the result of one-off events (natural disasters), or they operate on a longer timescale than SENSOR's twenty-year perspective (e.g. climate change or geological processes). Modelling the impact of disasters is a highly useful exercise, but it hardly fits with SENSOR's objective of assessing the potential impact of policies. Climate change is a different matter: although its impact may be difficult to assess for the 20-year time span we use in SENSOR, it is nevertheless a highly relevant issue when the slightly longer term is considered, a 50-year time span for instance. It is, however, also now generally accepted to be at least partially caused by human action, and can therefore be considered as an impact, rather than as a driving force in its own right.

Once this has been decided, which drivers should be chosen? This is to some extent dictated by the modelling framework, but of course that framework itself is designed on the basis of which variables one wants to explain and which ones not. In SENSOR, five factors have been chosen as drivers:

- demographic change within Europe
- the rate of participation in the labour force (in Europe)
- growth of world demand (outside Europe itself)
- the price of petroleum on the world market
- expenditure on research and development

To the extent that population growth is determined by births and deaths, fairly reliable forecasts can be made. International migration is much more difficult to predict, but Eurostat supplies population projections which include this aspect. These are a mixture of trend extrapolation with expert judgment on expected changes in trends.

There are also forecasts available for age- and gender-specific labour force participation rates, i.e. the percentages of males and females in each age group who are available for paid employment. These forecasts are based on past trends.

Whereas economic growth in the European Union is itself one of the variables we want to explain, the economic situation in the rest of the world should be regarded as exogenous, as one of the factors influencing European economic growth through the demand for European products and the competition for global natural resources. We shall introduce two drivers to reflect this: the growth in overall world demand (outside the EU) and the growth in demand for petroleum – which is the most important strategic natural resource which Europe needs from other parts of the world. For the former we have a projection from the OECD, for the latter a projection with the model PROMETHEUS – thus, both are founded on expert opinion.

As regards technology, in common with modern practice in economics, this is endogenised in econometric models and regarded as a function of knowledge, which can be modelled as expenditure on research & development and on education (Solow 2000). For simplicity's sake, we shall use only R&D expenditure as a driver in the model, but in reality the driver ought to include all aspects of the generation of knowledge, as well as its utilization (Ederer 2006). Three different forecasts were made for the baseline scenarios: the low forecast assumes stagnating expenditure; the reference scenario is based on trend extrapolation; and the high forecast assumes that the Lisbon Agenda target of 3% of GDP is achieved.
There are three other drivers which are important in explaining multifunctional land use:

- culture
- institutions
- policies.

Culture includes patterns of behaviour and of preferences. Important cultural drivers in our scenarios are consumer preferences (e.g. related to tourism, the demand for sustainably produced goods, a desire to live in the countryside), and the importance of environmental concerns. Institutions can be defined as sets of rules governing the relations between individuals or groups (Nabli & Nugent 1989). Markets and governments are examples of institutions, and their importance does not need elaboration. However, both culture and institutions change only slowly over time. Change in these drivers is a crucial factor, is overall social and economic change, and has a strong influence on policies as well. However, because such change is difficult to predict and because our approach is based on extrapolation of existing trend, it makes sense to exclude such change from the SENSOR

baseline scenarios. However, we must be aware that this exclusion is a simplification of reality.
Changes in policies are, of course, central to the purpose of SENSOR. Therefore, they are treated by separate policy scenarios, as argued in section 1 and described in section 4.

4 Storylines for the baseline scenarios in SENSOR

This section describes recent trends for the five driving forces listed above, and presents the projected figures to be used in the baseline scenarios.

4.1 Population

The 25 countries presently making up the European Union have experienced low and declining population growth over a long period, as Figure 1 shows. In the last few years we see a rise in the overall growth rate. In order to assess which trend is the most probable over the next twenty years – the short-term rising one or the long-term declining one, we must look at the factors determining population growth. This is done in Figure 2.

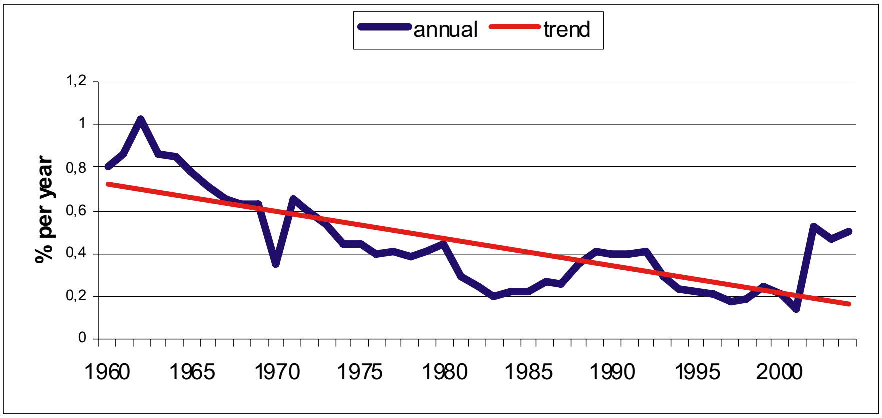

Fig. 1. Population growth in the EU-25, long-term trend Source: Eurostat

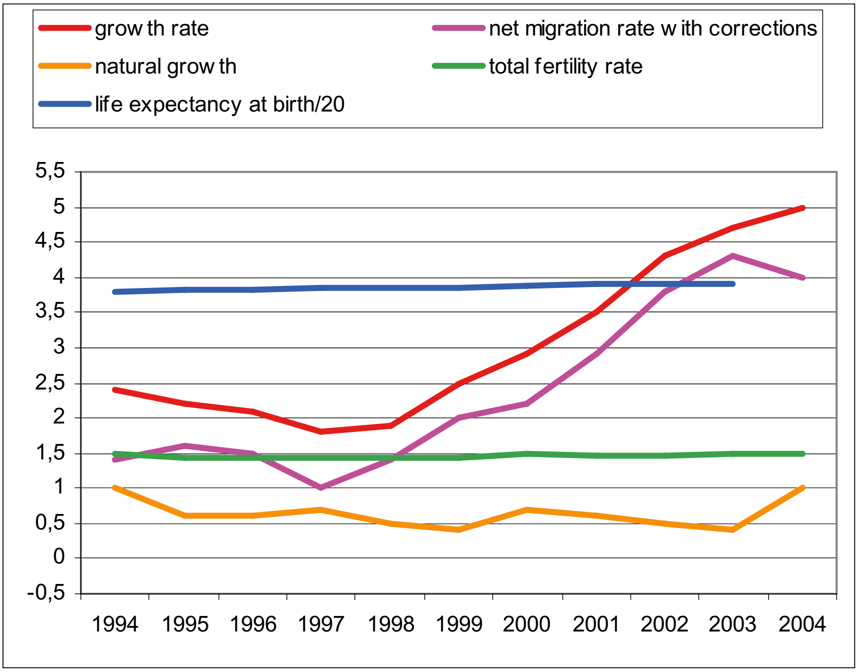

Fig. 2. Major demographic indicators 1994-2004, EU-25 Source: Eurostat

Population growth has two components: natural growth (the difference between births and deaths) and net migration (the difference between immigration and emigration). Natural growth is determined largely by three factors:

- the total fertility rate, i.e. the number of live children born per woman during her lifetime;
- life expectancy at birth; and
- the existing demographic structure, which can tell us how many women in the fertile age groups there are.

As can be seen in Figure 2, the total fertility rate has recently been fairly stable at close to 1.5 – well below the replacement rate of 2.1. It reached a low of 1.42 in 1999 and has since risen slightly to 1.5. Life expectancy has raised slowly but steadily, a result of continuous improvements in medical science and of rising prosperity.
The variations in natural growth shown in Figure 2 are due to changes in demographic structure. The EU population is characterised by a preponderance of people in the productive age groups 15-64, who make up 67% of the total population. This historically most favourable situation will not

last. As the age cohorts move upwards through the pyramid, it will become increasingly top-heavy: the number of children and young adults will decrease slowly as the number of elderly people rapidly increases. These changes in age distribution will cause the number of deaths to rise while births decline, and after 2010 natural growth will become negative. Overall population growth can then occur only due to net migration. As Figure 2 shows, migration is already a more important factor than natural growth. This makes population growth more difficult to predict, as migration is more subject to change and less predictable than natural growth.

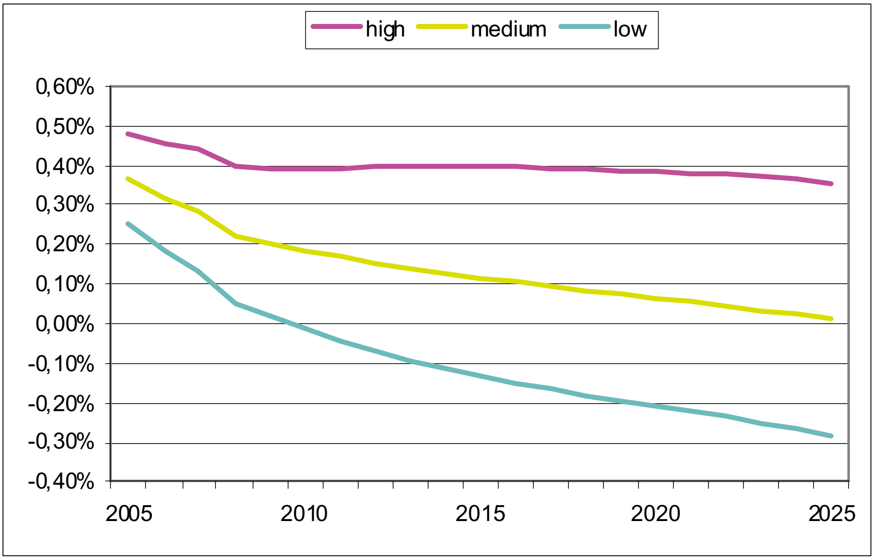

Fig. 3. Projected population growth in three scenarios - Source: Eurostat population projections

The SENSOR reference scenario corresponds to Eurostat's Medium projection. It sees fertility remaining well below the level of inter-generational replacement into the long term, but expects a small upturn in some countries. Life expectancy continues to improve but at somewhat slower rate than in recent decades, and immigration declines from its current level. The combined result of these assumptions is that in the reference scenario Europe's total population remains more or less constant up to 2025. The High population growth scenario has higher fertility (though still mostly below replacement level), longer life expectancy and more immigration (though still below recent rates). The combined effect is a modest growth in the total population. The Low scenario envisages fertility staying very low, with less improvement in life expectancy and much lower immigration. The overall effect is to project a marked decline in Europe's population in the not too distant future. Figure 3 shows population growth rates for the three baseline scenarios for the EU-25.

The differences between the total population of the EU today and in 2025 are quite small in all three scenarios: the variations are between a maximum growth of 8% and a maximum decline of 2%, with the medium scenario arriving at a total population 2.5% above the present level – or nearly 12 million persons in absolute figures. For the demographic structure of the population, however, the changes are more dramatic, as Table 1 shows.

Table 1. Major demographic shifts under three scenarios - Source: Eurostat population projections

Group	**change in numbers 2004-2025**	**% of total in 2004**	**% of total in 2025**
	Medium (reference scenario)		
children (0-14)	-9.2%	16.4%	14.4%
young persons (15-24)	-14.9%	12.7%	10.5%
most productive (25-54)	-8.8%	43.2%	38.3%
older persons (55-64)	30.4%	11.2%	14.2%
the aged (over 65)	40.7%	16.5%	22.5%
Total	2.5%	100.0%	100.0%
	Low growth		
Children	-23.5%	16.4%	12.8%
young persons	-20.3%	12.7%	10.4%
most productive age group	-11.4%	43.2%	39.1%
older persons	28.9%	11.2%	14.8%
the aged	37.1%	16.5%	23.1%
Total	-2.2%	100.0%	100.0%
	High growth		
Children	8.1%	16.4%	16.3%
young persons	-9.3%	12.7%	10.6%
most productive age group	-6.0%	43.2%	37.4%
older persons	32.2%	11.2%	13.7%
the aged	45.4%	16.5%	22.1%
Total	8.2%	100.0%	100.0%

In comparison with the situation in 2004, the numbers of children, young people and those in the most productive age group (25-54) will all have declined in 2025, both in absolute numbers and – more importantly – as a percentage of the total. In contrast, the numbers of older workers (55-64) and the aged are increasing rapidly. These shifts are even more pronounced under the low-growth scenario. Under high-growth assumptions the number of children grows, but the dependency ratio (the numbers of working age in relation to those too young or too old to work) becomes even more unfavourable. This is because both fertility and life expectancy are higher in the high-growth assumptions, so the first effect is to increase the numbers of children and old persons.

4.2 Participation rate

The proportions of people in the various age groups have, of course, large economic consequences. Within the 15-64 age group, actual participation in the labour force (defined as those either working or unemployed but looking for work or willing to work) also depends on age and sex: the young are often still in school, many people above 55 retire early, and among women the participation rate is still lower than for males – although the gap is narrowing.

There are large differences in sex- and age-specific participation rates between countries, and also in the way these rates are changing. For Europe as a whole, however, in recent years participation rates have risen in all groups, as Table 2 shows. The emancipation of women clearly shows both in their lower participation rate among the young (indicative of a high proportion receiving advanced education) and in the rising rates among both prime-age and older women. Over a longer period the picture is somewhat different: participation rates of women have increased for a long time, but those of the over -55s and the under -25s have declined because of early retirement and longer education periods, respectively (Carone, 2005).

Table 2. Labour force participation rates by age and sex, EU-25, 2004 (%)
Source: Carone 2005/ Eurostat

age group	males	change since 1990	females	change since 1990
15-24	48.1	+ 6.2	41.1	+ 2.5
25-54	91.8	+ 24.4	75.2	+ 53.5
55-64	54.3	+ 25.1	33.8	+ 69.8

Thus, apart from the total population and the numbers in the economically active age groups, we also need to forecast future changes in these age- and sex-specific participation rates, in order to arrive at the size of the working population. For the SENSOR reference scenario we take the most recent and most complete projections of the EU-25 workforce made by the European Commission (Carone, 2005). The reference scenario assumes that changes will be rather slower than hoped for in the Lisbon Agenda. This scenario is shown in Table 3. The high scenario assumes more rapid convergence, with more women and older workers in the labour force. In contrast, the low scenario assumes less rapid convergence and thus fewer female and older workers.

Table 3. Projected labour force participation rates by age and sex, EU-25, 2025 (%) Source: Carone, 2005

age group	males	change since 2005	females	change since 2005
15-24	50.7	+ 0.7	43.7	+ 0.7
25-54	94.1	+ 2.1	82.8	+ 7.0
55-64	65.9	+ 11.1	51.1	+ 18.0
65-71	13.9	+ 2.7	7.6	+ 2.7

As is clear from Table 3, participation rates are likely to rise in all groups, but at modest rates compared to recent trends. Except in the age group 55-64, there is relatively limited scope for a further rise in participation. Combining these outcomes with the changes in demographic structure described in the previous section, the total labour force as a percentage of the population will be virtually the same in 2025 as it is today: 48.1% as compared to 47.7% in 2005. What will change is that a larger proportion of the total workforce will consist of older people: the proportion of workers between 55-64 will increase from 10% today to 18% in 2025.

The high scenario actually leads to a smaller labour force (as a percentage of the total population) than the reference scenario, and similarly the low scenario leads to a larger labour force: 46.4% and 48.8%, respectively. This is because the numbers of people in the relevant age classes are lower in the high scenario, as explained above (and as can be deduced from Table 2); that effect outweighs the slightly higher participation rates.

4.3 World demand

World demand can be equated with total world income or total production. Looking at world economic growth over a longer period, there appears to be a slow downward trend, as Figure 4 clearly shows. When interpreting the significance of this phenomenon, we must take into account that the

EU itself is responsible for about 30% of total world production as measured in Figure 4 [1]. This means that the trend for the other 70% could differ significantly from that for the world as a whole.

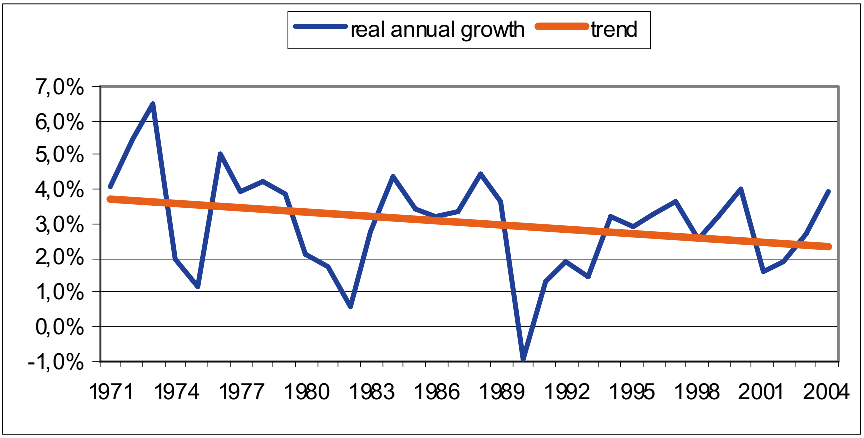

Fig. 4. World economic growth, 1971-2004 (GDP at market prices in constant US$ of 1990) Source: UN Statistics Division; processing: LEI

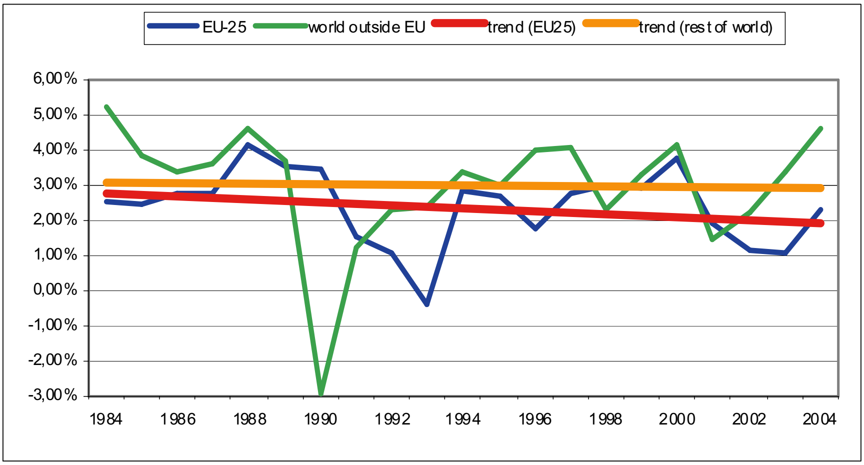

Fig. 5. .Economic growth in the EU-25 and the rest of the world, 1984-2004[2] (in constant 1990 US dollars), Source: UN Statistics Division; processing: LEI

[1] If we correct for differences in purchasing power, that percentage decreases to approximately 20%.

[2] The growth rate for the EU over the years before 1990 does not include the three Baltic states and Slovenia.

When we look at the picture over the last twenty years, this turns out to be indeed the case (Figure 5): the growth rate for the rest of the world has been almost constant on average. Most of the declining trend is precisely due to what is happening in the EU.

Simply extrapolating the trend of economic growth in the rest of the world for the next 20 years would mean annual growth rates decreasing slowly from a trend figure of 2.95% today to 2.8% in 2025. More sophisticated estimates have been made, however. An example is a projection for 2030, made by the OECD. In the OECD model (called JOBS[3]), the quantity of labour and its productivity are used as drivers (Bagnoli et al. 2005). For those regions of the world that are outside the EU, their projection is a more rapid decline than sheer extrapolation would predict (Figure 6). By 2025, the overall growth rate is 2.7%.

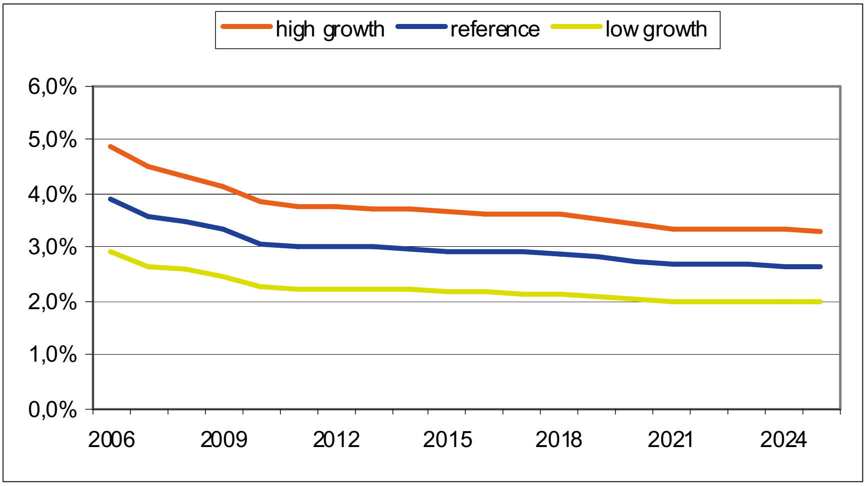

Fig. 6. Projection of growth in world production outside the EU-25 (real GDP at market prices) Source: OECD (Bagnoli et al. 2005), processing: LEI

The OECD does not provide contrasting scenarios. In order to construct these, we have used the calculations of the PROMETHEUS model (see the next section) as a basis for establishing probability intervals. According to those calculations, world GDP growth will be between 74.2% and 124.7% of the median projection with a probability of 95%. We have used these assumptions to compute our high- and low-growth scenarios, also depicted in Figure 6.

[3] JOBS is a global recursive dynamic computable general equilibrium model which captures international trade and focuses on environmental issues.

4.4 The oil price

The changes in world oil prices over the last 35 years would have been difficult to predict with economic modelling. Wild swings as a result of political events in the Middle East dominate the picture. Dramatic falls have been due to economic rather than political events, but these too were of a short-term nature (EIA 2005). However, if we discount the impact of these swings (to the extent that this is possible) and correct for the effect of inflation, the real cost of oil shows a modest rise over the period 1970-2000 and a more marked rise after that. This probably reflects the real scarcity of oil quite well: although since the publication of the Club of Rome report in 1972, the world has been clearly aware that oil stocks are not inexhaustible, for a long time the increase in demand has been outstripped by the discovery of new oil fields – partly previously known sources made viable by the increase in oil prices. Thus, known stocks of oil have continued to rise. The rise in recent years, however, even though political events (the war in Iraq and the fear of disruption by terrorists in Saudi Arabia) still play a part, is believed to be due mainly to market forces – in particular the growth in demand in the emerging Asian economies (Berkmen et al. 2005).

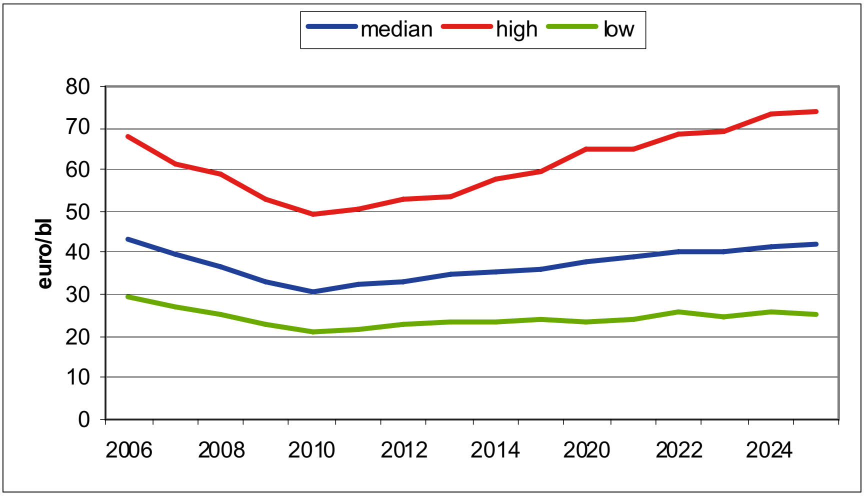

Fig. 7. Projections of the world oil price, 2006-2025 (in constant € of 1999) Source: PROMETHEUS (Institute of Computers and Communication Systems, National Technical University of Athens)

That view is reflected also in projections made with PROMETHEUS, a stochastic model of the world energy system developed at the National Technical University of Athens (Uyterlinde et al. 2004), shown in

Figure 7. As the figure shows, the expectation is that oil prices will decrease over the next few years, but rise in the longer term. The high and low variants represent the 95% probability interval.

This model uses projections of world GDP on the basis of the SRES-B2 scenario of the IPCC. This results in a global growth rate of 3.0% over the period up to 2020 and 2.6% thereafter. That rate is quite close to the world growth rates of the OECD projection described in the previous section, which are 3.0 and 2.5 respectively.[4]

The EU itself exerts a considerable influence on the world oil market, both as a consumer and as a producer. Since its growth is lower than that of the world as a whole, however, the percentage of world oil which it consumes is decreasing. Moreover, because energy efficiency in Europe is relatively high and (driven by the increasing cost of energy) increasing, the growth in demand for energy is less than the growth in GDP. On the other hand, because European oil and gas reserves are being depleted rapidly, our dependence on imported fossil fuels will grow, despite the development of alternative sources of energy (Uyterlinde et al. 2004).

4.5 Research & Development efforts

Innovation – in marketing and organization as well as in technology – exerts a major influence on economic growth by raising the productivity of people, capital and natural resources. As pointed out in section 2, R&D expenditure is one driver of innovations, and therewith of economic growth. It is itself also strongly influenced by the level of GDP (rather than by the GDP growth rate), in that the richer a country is, the more it can afford to spend on R&D – even as a percentage of total GDP. This is why the latter figure is lower in China than in the EU, even though China is a much more dynamic economy; similarly, within the EU the poorer countries tend to spend a lower proportion of their GDP than the richer ones.

Data on total R&D expenditure in the EU are somewhat sketchy, however. In real terms and for the EU as a whole, they are available only from 1999, which does not give us much of a trend (Figure 8). We can see that growth in R&D expenditure has been modest (2.5% per year in real terms); that almost two thirds of the total comes from the private sector; and that the growth has been mostly in academic research. Business has been reluc-

[4] Policies are assumed to remain constant, in line with the general assumption for our baseline scenarios. However, a carbon tax is assumed to be in force in OECD countries from 2005, and in non-OECD countries from 2011 (Uyterlinde et al. 2004:87).

tant to invest in the recent years of slow economic growth, and governments (desirous to keep their budget deficits within bounds) have been even shyer, notwithstanding a professed concern for promoting the knowledge economy.

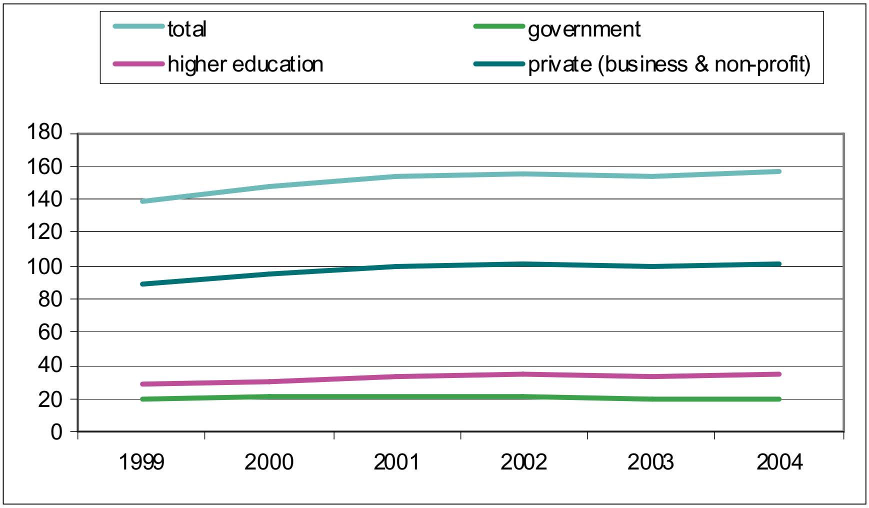

Fig. 8. R&D expenditure in the European Union, in billions of purchasing power standards (constant prices of 1995)
Source: Eurostat

For the 15 pre-2004 member states, a somewhat longer time series is available. These figures show that R&D efforts in the private sector follow the business cycle fairly closely; the expenditure on academic research shows a long-term rising trend, whereas public support to R&D (outside university programmes) appears to have stagnated for a long time. Also significant is the difference between the old and the new member states: although the latter take up only a small proportion of overall R&D spending, growth is much faster there. R&D expenditure in recent years falls well short of the target specified in the Lisbon Agenda of the EU, which aims at increasing R&D to 3% of GDP by 2010. That target was proclaimed in 2000, since when the actual R&D intensity (as the quantity is called) has fluctuated around 1.9%. Thus, the chance of achieving the Lisbon target is rather remote. We shall use the target as a basis for our high-growth scenario. The business-as-usual scenario we shall base on simple extrapolation of the trend for the EU-15 over the last 14 years. Whereas this may seem somewhat pessimistic, because the new member states have faster growth R&D expenditure, we believe that it is realistic as we shall presently argue.

The EU is falling behind rather than catching up, as some data collected to review progress on the Lisbon Agenda make clear: in Europe, although expenditure on education is not far behind the USA, expenditure on tertiary education is much higher in America. It is then not surprising that the number of researchers in Europe is also relatively low and increasing only slowly. Finally, there is a tendency for more investment in R&D flowing from Europe to the US than the other way round, which indicates that Europe is losing its attractiveness as an environment for innovation (Duchêne & Hassan 2005). As these authors state: “It risks leading Europe into a worrying vicious circle as the loss of high value-added R&D activities and jobs is undermining further its capacity to retain such activities.” (*Ibid.)*

These observations must inform our perspective towards the future. Hence, our business-as-usual scenario is based on the expectation that the effect of the vicious circle referred to above will be minor, and just enough to cancel out the effect of higher R&D growth in the new member states. For our low-growth scenario, however, we assume that R&D expenditure for the EU as a whole will stagnate in real terms at the 2004 level as a result of the low priority of higher education, and the attractiveness of more dynamic parts of the world as research and innovation environments. The high-growth scenario assumes that the target of 3% of GDP by 2010 is achieved for the EU as a whole. After that date, R&D expenditure will continue to rise, but a slower rate to reach 3.5% of GDP by 2020; that same rate will then be maintained until 2025. Figure 9 shows the three trends.

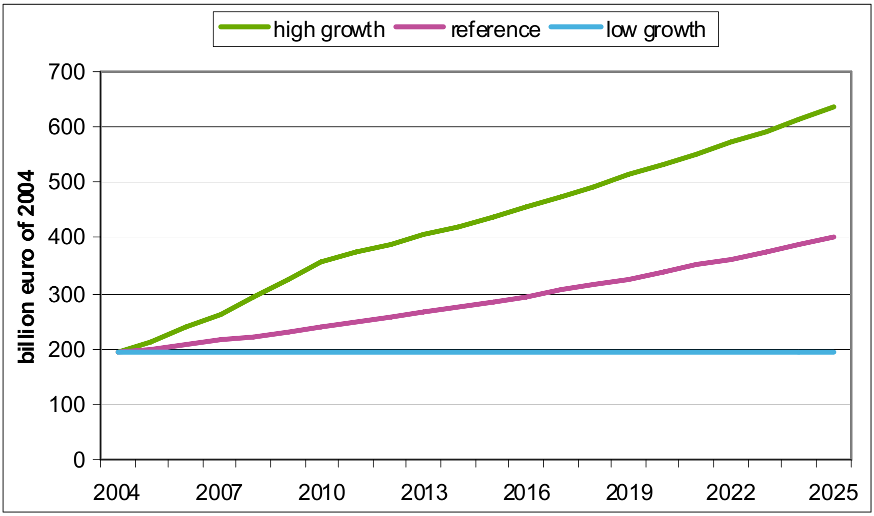

Fig. 9. Projection of R&D expenditure, 2005-2025

5 The idea of policy cases

As pointed out in section 1, a policy case represents a problem area within which policy scenarios can be formulated by the end user. To do this, the case must contain variables (representing policy instruments) which the end user can manipulate. These policy variables must be designed in such a way that said end user will not need specialist knowledge on the models powering the tools, nor should he have to wait for hours for the various models to run.

This is possible if the various models and the links between them are replaced by simplified functions (*response functions*) representing the correlations between policies, land use change and sustainability indicators. The models are used to find these correlations. Thus, the models are used to calculate the sustainability impact of a limited number of settings for each policy variable. This is a fairly complex operation requiring a number of iterations where parameters values in the various models are adjusted until a reasonable degree of convergence between models is achieved. However, once we have outcomes for several values of the policy variable, we can estimate the direct correlation between the variable and the sustainability impact. A function can be constructed for that correlation, and this function can now be used to calculate the impact of any other values of the policy variable – without having to return to the models. How this works is explained in greater detail in chapter 8 of this volume.

Five policy cases have been selected for modelling in SENSOR[5]:

- Bioenergy, where various options for promoting both the production and consumption of energy from biomass are examined;
- The coming financial reform of the EU budget in 2012, where various options of continuing the Common Agricultural Policy (CAP) may be weighed against the proposal to promote the knowledge economy instead;
- Biodiversity policies, as related to the conservation of nature areas, but also in relation to agriculture, forestry, tourism, etc.;
- The forest strategy;

[5] A sixth case had originally also been envisaged, namely that of regional support designed to reduce the economic and social disparities between European regions, as presently contained in the structural and cohesion funds. This case is highly relevant politically, as it is the second largest expenditure on the EU budget (after the CAP). However, we do not presently have the modelling tools to adequately analyze the impact of these policies. It is to be hoped that future extensions of the toolbox may enable us to construct such a policy case.

- European transportation policy, for instance related to the fiscal treatment of aviation.

Together, these policy cases make up the full range of policies for which SIAT can be used. They cover all six sectors analysed by SENSOR, and all of them are concerned with policies which will have an influence on multifunctional land use. To be sure, SIAT can be adapted for completely new policy cases (as well as additional policy variables in existing cases), but this would require building them into the various models used in SENSOR, and running the full chain of models in order to establish the necessary response functions. The policy case for which the storyline has been elaborated in most detail so far is the one for bioenergy, which is described in the next section. All of them, however, follow the same outline which we shall now proceed to describe.

5.1 What a policy case should look like

A policy case description must first contain a statement of the problem which the policy or set of policies is designed to solve or mitigate. That statement leads naturally to the goals which the policies are supposed to contribute to. A *goal* is seen here as the ultimate rationale of an action. It differs from an *objective*, which is the direct aim that the action is deemed to be able to achieve. For instance, an authority may take measures to protect the habitat of a particular species. It hopes therewith to contribute to the goal of biodiversity, but it cannot be certain that biodiversity will improve as this will depend on other factors beyond the control of the authority in question. However, it can be held to account (a) over whether it effectively protects the habitat (its objective); and (b) over whether this helps biodiversity (i.e. whether the objective contributed to the goal). One might say that the goal is the reason why an objective is thought to be worth achieving. It should normally be possible to identify goals as falling into one of the three dimensions of sustainability – social, environmental or economic.

The term policy itself we shall define loosely as a documented statement on actions which an entity (in this case the European Commission) intends to undertake. Apart from a statement of the objectives and the goals, a policy must contain a list of the means by which one hopes to achieve the objectives. These means we call *policy instruments,* of which there are several types. To the extent that a policy is aimed at influencing behaviour among the public, or on the part of companies, three types can be distinguished which have been dubbed carrots, sticks and sermons (Collins et al. 2003). Carrots are rewards for behaviour which promotes the policy objective (e.g. tax breaks for investment in blighted areas); sticks are punishments for the opposite behaviour (e.g. a law to enforce the wearing of seatbelts); and sermons are campaigns for telling the public that it ought to behave in a certain way (for instance practising safe sex to avoid AIDS). An alternative to sermons is simply providing information, without any exhortations to the public. In addition to these instruments aimed at influencing behaviour of others, a policy-making authority may also undertake direct actions which can contribute to the objectives of a policy: creating institutions, and undertaking or commissioning research. Finally, it may decide to do nothing – a serious and sometimes justifiable option, which would return us to the baseline scenario.

Not all policy instruments are equally suitable for modelling – and for SIAT. The impact of setting up an institution, for instance, is difficult to predict quantitatively. Realistically, 'carrots', 'sticks' and research are the instruments that best lend themselves to impact assessment. As we have already seen, in modelling these policy instruments are represented by policy variables. Such a variable may represent a single policy instrument, but also several of them in conjunction. There are two reasons for this: firstly, to reduce the amount of modelling work; but more importantly, to be able to assess the impact of a package of measures which in practice are likely to go together.

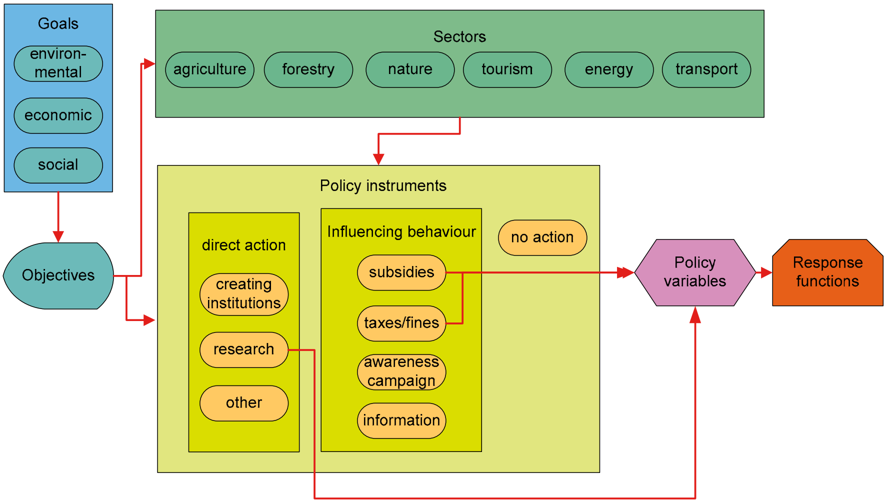

Fig. 10. The structure of a policy case

It needs to be understood here that the response functions in SIAT will not be capable of interacting with one another: each function will be represented by a 'knob' on the screen, and only one such knob at a time can be turned. In other words, it will not be possible to assess the impact of several measures simultaneously – unless a response function for those measures together has been designed. This is precisely what the modellers will do. Figure 10 shows the relationships between the various terms used here.

6 The bioenergy case

Bioenergy has been chosen as a policy case because (a) it is an important issue in EU policy and is likely to remain so for some decades to come; (b) the production of bioenergy has a significant impact on land use; (c) it cuts across several sectors: agriculture, forestry and energy – and possibly nature as well, since bioenergy production may compete with natural land. Finally, (d) through existing instruments, impact assessments and extensive literature, it can provide a good basis for ex-post validation of results.
Following the schedule outlined in section 4, we should begin with a discussion of goals: the problems which a bioenergy policy is supposed to help solve. This leads to a consideration of objectives, the concrete things which the policy is expected to achieve. Policy initiatives already undertaken by the European Commission are the best source for this. Next, we shall define policy instruments which appear suitable for achieving these objectives (including such instruments as have already been thought of by the Commission), and convert them into policy variables for modelling.

6.1 Goals

There are three concerns which are leading many countries towards promoting the use of bioenergy:

- The greenhouse effect: burning fossil fuels means releasing carbon dioxide into the atmosphere which causes a rise in temperature. Burning biomass also releases CO_2, but in this case the CO_2 has first been absorbed from the atmosphere.
- The looming exhaustion of petroleum and natural gas: supplies are finite and non-renewable, and will eventually become depleted.
- Security: even while fossil fuels are still relatively abundant, many countries are concerned about the risks caused by dependency on an imported resource – especially where this resource comes from potentially

hostile or volatile countries and must be transported over long distances where transport routes are vulnerable to disruption.

Although the last two goals are closely related, they may give rise to different policies and the outcomes of these policies will be evaluated differently according to which goal one is looking at. For instance, husbanding one's own fossil oil and gas deposits will help to provide security against disruption of transport routes, but will not postpone the day when all deposits will be depleted; conversely, importing bioethanol from Brazil will help with the second goal, but not with the third.

6.2 Objectives: EU policies on bioenergy

The European Union has supported renewable energy since the 1980s, at first mostly by funding research to promote technological progress. This support has helped to make European companies major players in the market for renewable-energy technology, and promoting the growth and competitiveness of industries related to renewable energy is an important collateral objective of European energy policies.

More needed to be done in order to meet the greenhouse-gas emission targets of the Kyoto Protocol, however, and in 1997 the Commission published a White Paper on Renewable Sources of Energy (CEC 1997). This document gives an indicative target, for both the then 15 member states and the prospective new members, of doubling the overall share of renewable energy in the EU from about 6% in 1995 to 12% by 2010. Bioenergy was seen as the second most important source of renewable energy, after hydro-power. Since the perspective for expanding the latter is limited (due to environmental considerations which militate against large dams), bioenergy is set to become the most important, accounting for three-quarters of the target figure for all renewables.

This White Paper has been the basis for further policy initiatives on the part of the European Commission. For bioenergy, the most important documents since the White Paper have been the Biofuels Directive of 2003, specifying that 5.75% of all petrol and diesel should be biofuels by 2010; and the Biomass Action Plan (BAP) of December 2005 (CEC 2005). This is mainly a statement of what the Commission intends to do for promoting the use of biomass. The BAP sets the target for the use of biomass in 2010 at 150 Mtoe – more modest than the White Paper, considering that this target is for the EU-25, not for the EU-15. The three uses to which biomass can be put - heating, electricity generation and transport fuels – are all discussed in the Plan. Measures to promote the demand for bioenergy as well as for stimulating its supply are proposed (CEC 2005).

The principal objectives which 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.

6.3 Policy instruments

The various policy documents of the European Commission concerning bioenergy contain the instruments listed in Table 4, following the schedule described in the previous section.

Table 4. Policy instruments for promoting bioenergy

Carrots	Sticks	Sermons	Information	Research	Institutions
Reduction of excise duty for biofuels	Compulsory percentage of biofuel in transport fuels	Work with NGOs and local authorities	Set up networks for communicating information in the fields of technology, finance, and environment	On supply chain	Adapting regulations to remove barriers to bioenergy use
Subsidy for energy crops		Institute awards	Organize conferences	On efficiency of production	Standardisation and labelling of products
Support to investment				On reducing negative environmental effects (solid waste)	Trade agreements on biofuels
Promoting use of surplus forest growth for bioenergy					
Promoting use and modernization of district heating					

It is from these instruments that policy variables must be selected. However, there is an additional issue which, although discussed in the Biomass

Action Plan, has not been assigned a particular policy instrument. This is the question of whether bioenergy should be produced domestically or imported. Allowing imports makes bioenergy cheaper and therefore makes it easier to achieve the two goals of mitigating climate change and averting the depletion of fossil fuels; however, it goes against the third goal of being less dependent on imported energy.

At present, the importation of ethanol is restricted by tariffs: € 10.2/hl of denatured alcohol (i.e. made unsuitable for human consumption) and € 19.2 for undenatured alcohol, although a large part of actual imports are from countries which can export duty-free to the EU (CEC 2005). Imported bioethanol can be up to 25% cheaper than local production, so without tariffs the European ethanol industry probably would not exist. As for biodiesel, this is protected from imports in a different way. It is currently mostly produced from rapeseed, and the EU is competitive for this crop. There are no import tariffs on vegetable oil, so in principle there is considerable scope for using imported oils, notably palm oil which is much cheaper than rapeseed oil. However, biodiesel must satisfy a European standard called EN14214, the specifications of which are based on rapeseed. This makes it very difficult to produce biodiesel from other crops. Modifying this standard would open the door to imported biodiesel feedstock.

In addition to import restrictions, there exist some subsidies for bioenergy crops. There is a premium for energy crops of € 45/ha, for a maximum of 1.5 m ha, on non-set-aside land. Another important policy is laid down in the Blair House Agreement of 1992: the EU and the United States set a ceiling on the production of oilseeds for energy on set-aside land; this ceiling is equivalent to about 1 m hectares of oilseeds (Rabobank 2005). In principle, it would be possible to increase the former of these subsidies, and also to tighten the aforementioned import restrictions. However, this is not a very realistic option in view of the general direction of world trade negotiations. Production subsidies for agricultural crops would fall into the so-called amber box, which means that the EU is bound under the terms of the Uruguay Round to limit the total amount of subsidies to a maximum of 5% of total agricultural production. This virtually excludes any scope for subsidising oilseed, sugar or starch crops for bioenergy. It is different for low-value crops, which can be feedstock for the so-called second-generation biofuels (lignocellulose-based ethanol). These crops, which include miscanthus, eucalyptus and the like, are unlikely to be traded over large distances. However, if they are used to produce ethanol, the end product will compete with imported ethanol.

6.4 Policy variables

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

- Promotion of bioenergy production and consumption, in the following forms:
  - a mandatory percentage of biofuel in transport, which before 2025 will include aviation and sea transport as well as road transport; the percentage may vary between 2% and 25%.
  - subsidies for research and development of bioenergy in all its forms, up to a total of € 5,000 million per year for the EU as a whole;
  - subsidies (including tax breaks) for the production of heat and electricity from biomass (not including first-generation biofuels from agricultural crops), up to a total of € 10,000 million per year in the most ambitious scenario.
- Lifting of 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.

The first variable contains three different policy instruments, which move in tandem from a low to a high level of bioenergy promotion. The second one is a ‘toggle switch’, enabling the end user to see the impact of each of the scenarios constructed with variable 1 under free-market as well as under protective conditions.

It must be emphasised here that the models are capable of calculating any combination of these four instruments. In order to limit the amount of modelling required, however, only the most plausible combinations have been selected to construct response functions, with which an immediate answer to the question posed by the end user can be given.

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Cross sector land use modelling framework

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Abstract

The purpose of the model component in SENSOR is to quantify the effects of a comprehensive set of policies on land use. The need to include interaction between sectors as well as a high level of detail for each sector calls for a combination of *sector specific* and *sector wide* models. This chapter describes the modelling system, with emphasis on the linking of the models to a coherent system. Five sectors of significant importance for land use are modelled individually: Forestry, agriculture, urban land use, transport infrastructure and tourism. All models are connected as sub-modules to an economy-wide partial econometric model. In addition, a land cover model is used to disaggregate land use down to 1 km grid resolution.

The linking of such a diverse set of models in a consistent way poses conceptual as well as practical issues. The conceptual issues concern questions such as which items of the models to link, how to obtain a stable joint baseline scenario, and how to obtain a joint equilibrium solution for all models simultaneously in simulation. Practical issues concern the actual implementation of the conceptually sound linkages and provision of a workable technical solution. In SENSOR, great care has been taken to develop a sound linkage concept.

The linked system allows the user to introduce a shock in either of the models, and the set of results will provide a joint solution for all sectors modelled in SENSOR. In this manner, the models take a complex policy scenario as argument and compute a comprehensive set of variables in-

volving all five sectors on regional level, which in turn forms a basis for distilling out the impact on sustainability in the form of indicators. Without the extensive automation and technical linkages, it would not have been possible to obtain a joint equilibrium, or it would have required exorbitant amounts of working time.

Keywords

Model linking, sustainable land use, cross sector modelling, iterative re-calibration

1 Introduction

A key characteristic of the SENSOR project is that it applies a *cross-sector* approach to land use. This approach acknowledges that different sectors of the economy interact via shared resources, of which land is of most interest in SENSOR. Although a cross-sector approach enables capturing important interactions between sectors – and thus analysing important topics – it brings the modeller to a classical dilemma: On the one hand, a model with great scope is desired in order to span across the sectors of interest; on the other hand, models spanning several sectors can pay less attention to the details of each sector.

Due to the trade-off between scope and detail, models tend to specialise in either one. In SENSOR, we attempt to resolve that dilemma by using a combination of models. For each of the five sectors of interest, one specialised sector model is *linked* to an aggregated cross-sectoral model. In that way, the advantages of detail in each sector model can be exploited, and at the same time the *interactions* between the sectors are captured by the aggregated model[1]. For example: The agricultural sector model in SENSOR is fairly detailed concerning agriculture, but omits all other land uses. In contrast, the macro model entails competition for land by all sectors. By a proper linking, the strength of the detailed agricultural model

[1] The reader may be familiar with EURURALIS and SCENAR2020; two projects with similar cross sector modelling ambitions. SENSOR differs from the EURURALIS project which uses only a cross sector model (Klijn, et al. 2005; MNP and WUR, 2007) and it adds to the SCENAR2020 study a better linking system and the inclusion of other sector models than agriculture (Nowicki, et al . 2006).

can be utilized without sacrificing the competition between sectors provided by the macro model.

The purpose of this chapter is to provide a description of the linked system of models used in SENSOR, with emphasis on *how the models work together*, in order to provide a consistent and comprehensive picture of the cross-sectoral land use modelling. First, we introduce the land balance concept used. Second, a brief description of each individual model is presented, sufficient for clarifying its role in SENSOR. The model descriptions contain references for further reading. Third, the linkages of the models are described in greater detail. Two final sections provide discussions and a summary.

2 Land balances

The modelling of *land use* is central to SENSOR. The total land area is divided into agriculture, forestry, urban (including tourism), transport infrastructure, and land unsuitable for or legally exempted from exploitation. The economic value of land depends strongly on its use, with reference to the broad classes mentioned above: The value of land for urban, tourism and transport use is higher than that for agriculture and much higher than that of forestry. Therefore we do not model a fully integrated market for land but work with the principle of hierarchical markets with inferior and superior land claims. Relative to agriculture, the claims for urban, tourism[2] and transport are superior and the claim from forestry is inferior. The land balance concept is illustrated in Figure 1.

The superior land claims together with land "unsuitable" for exploitation (i.e. areas with strong constraints in terms of soil quality and/or climate) and land under "nature protection" are not available for agriculture. Those land claims are symbolised by the shaded rectangles on the right hand side in the Figure, and they *limit* the total amount of land available for agriculture (asymptote L) in each country. Given the total amount of land available for agriculture, the supply of land for agriculture (supply schedule S, see also Meijl et al., 2006) depends on the land price in agriculture (λ, measured on the vertical axis). The price reflects the marginal cost of taking land into agricultural production. As indicated in the Figure, that curve approaches the "asymptote" L as the agricultural land price increases. Thus, the more land is used in agriculture, the higher the land price needs to be, as it becomes increasingly difficult to make additional

[2] The tourism sector has no own land use class, but is part of the urban land use.

land suitable for agriculture. The agricultural land demand (*D*) reflects the marginal productivity of land in agriculture. The amount of land use in agriculture (x) is determined by the price equilibrium, $S(\lambda) = D(\lambda)$. The amount of land ($L - x$) that is not used by agriculture is potentially available for forestry (or other climax vegetation)[3].

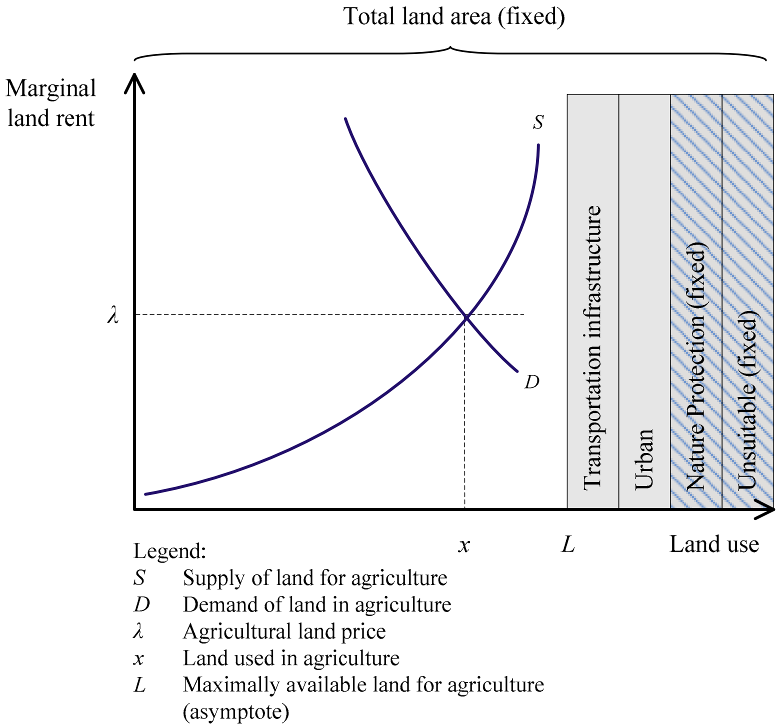

Fig. 1. Land balance in SENSOR. Land use for tourism is included in "urban".

The following example illustrates the mechanism: A "positive" shock to agriculture (e.g. increased food demand, increased subsidies, technical progress or rising commodity prices) works in three steps as described above (the steps are simultaneous; the order is intended to illustrate the economic hierarchy). Step 1: GDP, investments etc. change, and may influence the superior land claims "transportation infrastructure" and "urban". The asymptote L is shifted (small effect). Step 2: The demand schedule D is shifted to the right, determining a new agricultural land use x

[3] *Land potentially available for forest* is modelled on the level of land balances, but consists of different land cover classes. These classes represent different stages in the succession to forest and the *actual forest area* itself.

(the main effect). Step 3: The area potentially available for forestry, $L - x$, is reduced.

3 Overview of the models

In SENSOR we include a detailed macro-econometric model called NEMESIS, which models cross-sector impacts (see section 3.1). The sector models are CAPRI for agriculture, EFISCEN for forestry, SICK for urban, B&B for tourism and TIM for transport infrastructure (see sections 3.2 to 3.6). An important characteristic of NEMESIS is its land use module which includes three of the five sector models (SICK, TIM, and B&B models), as sub-modules. Using the SICK model, NEMESIS calculates land claims by housing as well as commercial and industrial building. Furthermore, NEMESIS derives the land claims for rail and road transport infrastructure from the TIM model, and uses the B&B model to compute the land used by tourism.

SENSOR also contains a land cover model called DYNA-CLUE. DYNA-CLUE disaggregates the land use on member state level computed in NEMESIS down to 1 km² grid units, and adds the land cover types: recently abandoned arable land, recently abandoned grassland, (semi)natural cover, forests and stable areas. It also distinguishes permanent crops from rotational crops. It then re-aggregates the land available for agriculture and forestry to sub-national regions for use in CAPRI and EFISCEN respectively. Before proceeding with a more thorough discussion of how the models are linked, we provide a brief overview of each model.

3.1 Macro- econometric model: NEMESIS

The economic model that makes the distribution of land claims between the sectors on national level is called NEMESIS (New Econometric Model for Evaluation by Sectoral Interdependency and Supply). It is a detailed macro-econometric model built for each country of the EU27 (plus Norway, USA and Japan) that uses as main data source EUROSTAT, and specific databases for external trade (OECD, New CRONOS), technology (OECD and EPO) and land use (CORINE 2000). NEMESIS is recursive dynamic with annual steps.

NEMESIS distinguishes 32 production sectors, including Agriculture, Forestry, Fisheries, Transportations (4), Energy (6), Intermediate Goods (5), Capital Goods (5), Final Consumption Goods (3), Private (5) and Public Services (1). Each sector is modelled with a representative firm that takes its production decisions given its expectations on marginal production capacity expansion and input prices. Firms' behaviour are based on new growth theories, where endogenous R&D decisions allow firms to modify the efficiency of the different inputs (biased technical change) and the quality of output (Hicks neutral technical change).

On the demand side, the representative household's aggregated consumption is indirectly affected by 27 different consumption sub-functions through their impact on relative prices and total income, to which demographic changes are added. Government (public) final consumption and its repartition between Education, Health, Defense and Other Expenditures, are also influenced by demographic changes. Please see Brécard et al. (2006) for a fuller description of NEMESIS.

3.2 Urban area: SICK

To be able to predict land use by urban areas, two types of enhancement to the NEMESIS model have been introduced. One principally relies on *bid-rent theory* for conversion of land into urban uses (Walker and Solecki, 2004). The direct effect of proxy-variables, such as GDP per capita and population growth upon urban expansion as measured in the CORINE datasets for 1990 and 2000 have been estimated (for a similar approach see Alig et al., 2004; Angel et al., 2005). The other type of enhancement uses a *Stock-flow approach* (DiPasquale and Wheaton, 1994; Mayer and Somerville, 2000) to model the supply of buildings, and combines this with a technical coefficient for land use of buildings estimated based on the urban land cover in the CORINE dataset for 2000. In this approach the urban land use is treated as a demand derived from the demand for housing (Muth, 1972) for which many of the relevant processes are already represented in the model. Its main basis is the net investment demand for buildings, which is modelled within the NEMESIS as part of the capital stock for each economic sector. Net investment demand for housing is added to the model as a function of real disposable income, real interest rates, and building prices. With the purpose of comparison and validation of the result both approaches to the prediction of future urban expansion have been employed.

3.3 Agriculture: CAPRI

The agricultural sector is the most important user of land in many regions, which motivates the use of an agricultural sector model to analyse the implication of policy scenarios in greater detail. The sector model used in

SENSOR is called CAPRI (see Britz 2005 and references therein for a full documentation). CAPRI offers a detailed depiction of the agricultural sector on regional level in the EU, with around 250 regions and around 50 agricultural primary and secondary products. CAPRI also contains a worldwide trade module, where 18 regional blocks trade bilaterally.

Agricultural production in European regions is determined by a mathematical programming model, which maximizes gross value added of a representative regional farm subject to technological constraints and a behavioural quadratic cost term. The quadratic cost term is derived from Positive Mathematical Programming (PMP, see Howitt, 1995), but the methodology has been improved in several respects: The problem of linear dependence between "calibration bounds" and model constraints, leading to unidentified dual values, has been alleviated by substitution of prior dual information for such model constraints in the calibrations step. In practice this means that regional grassland and arable land balances in the calibration step have been replaced by regional rental prices of grassland and arable land. Furthermore, prior information regarding the slope of the marginal cost curve (in the form of point supply elasticities) is exploited to resolve the indeterminacy of parameters in the "original" PMP method[4]. The behavioural cost term, thus specified, allows exact calibration of the model to one observed solution (as regards primal as well as dual variables, or decision variables as well as economic rents), and a first order approximation to supply *behaviour* in that point.

Demand is modelled on member state level and for about 40 regions in rest of the world using a Generalized Leontief expenditure system. The three sectors dairy, oil seed crushing and animal feed mixing, are modelled by profit function approaches. The European countries and the 40 world demand regions are aggregated into 18 trading blocks, each with its own set of agricultural trade policy instruments. Products of different geographical origin are distinguished on the demand side in a manner based on Armington (1969), similar to the specification in the GTAP model (Hertel 2004).

CAPRI contributes to SENSOR by implementing many policy instruments that are important determinants of regional land use, thanks to the model's detailed representation of the common agricultural policy (CAP) of the EU. CAPRI also serves to provide detailed results on agricultural land use on regional level, to provide NEMESIS with a land rent feedback and finally, via its technology representation, to provide inputs for the computation of environmental indicators in SENSOR.

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[4] Alternatives for the standard PMP approach are described in Heckelei and Britz (2005).

3.4 Forestry: EFISCEN

The forestry sector is the second largest user of land in Europe. Currently, 1-74% of the land area in European countries is covered by forest, with a European average coverage of 38% (FAO, 2006). Not only the extent of the forest *area* is important for sustainability, but more so the management practices employed on that area. The European Forest Information SCE-Nario model (EFISCEN) (Schelhaas et al., 2007) projects forest resource development on a given forest area and for a given demand for wood and management regime at European, national or regional scale (EEA, 2006; Karjalainen et al., 2003; Nabuurs et al., 2001; Schelhaas et al., 2006a).

The forest area is derived from national forest inventories along with the average growing stock and the annual increment. The forest area is divided into forest types that are defined by region, owner class, site class and/or tree species. The number of forest types differs per country and the detail level of the forest inventory data determines how many forest types can be distinguished. European wide data are gathered in the EFISCEN European Forest Resource Database (Schelhaas et al., 2006b).

In EFISCEN, the state of the forest is described in a matrix for each forest type separately, in which area is distributed over age and volume classes. Transition of area within the matrices represents different processes such as ageing, growth, mortality and harvest.

The transition of area can be influenced by wood demand, forest management and changes in forest area. Wood demand is in SENSOR projected by NEMESIS and is the main determinant of forest resource utilisation. If wood demand is high, management is intensive, and if wood demand is low, management is not intensive. Forest management regimes are based on a country-level compilation of management guidelines (Yrjölä, 2002). Forest area changes, resulting from aforestation and deforestation, are obtained from projections by DYNA-CLUE.

Based on the information mentioned above, EFISCEN projects stem wood volume, increment, age-class distribution, removals, forest area, natural mortality and dead wood for every five year time-step. With the help of biomass expansion factors, stem wood volume is converted into whole-tree biomass and subsequently to whole tree carbon stocks. Information on litterfall rates, felling residues and natural mortality is used as input into the soil module YASSO (Liski et al., 2005), which is dynamically linked to EFISCEN and delivers information on forest soil carbon stocks.

3.5 Tourism: B&B

The objective of the tourism modelling in SENSOR is to assess and predict the land requirement for tourism infrastructure developments per NUTS-X[5] region for the base year 2000 and for the year 2025. This requires, in the first place, a tourism demand model – linked to the overall NEMESIS – predicting tourism numbers. Secondly, to be able to distribute the flows of tourists from tourist generating regions to the tourist receiving regions, a bilateral tourism flow matrix is established and connected to the demand model. Thirdly, to distribute the flows at sub-national levels to the NUTS-X regions, tourism-attraction has been modelled and a tourism attraction index has been established. Finally, the immediate land use of tourism overnight facilities have been estimated and may hereby be separated from the urban land uses in which it is currently included. Eventually, the overall model should be able to predict how changes in demand is distributed at national and sub-national levels and compute the resulting spatial land use changes in tourism facilities. The tourism demand is modelled by an AIDS (Almost Ideal Demand System) following Deaton and Muellbauer (1980)[6].

3.6 Transport infrastructure: TIM

The main objective of the transport infrastructure model (TIM, see Ortiz 2005 and Ortiz 2006) is to predict the land requirement for new transport infrastructure developments in the EU27 given NEMESIS' projections of the demand for transport in 2025. NEMESIS' projections of the demand for transport are based on projections of key socio-economic indicators such as oil prices, GDP and population for the period of analysis, and are estimated from the households' and firms' total expenditures with transport. The total demand for transport in NEMESIS distinguishes total *passenger* demand for transport and total *freight* demand for transport, by transport mode: *road*, *rail* and *air* transport. The modelling approach for transportation infrastructure in SENSOR involves linking the demand for transport of households and firms first to road and rail extension and then

[5] All regions in SENSOR are official regions following the official nomenclature NUTS of Eurostat. Each member state is modelled either at NUTS-2 or NUTS-3 level, depending on what was deemed to be the appropriate resolution for that member state. The resulting total set of regions (the union over all member states) thus contains both NUTS-2 and NUTS-3 regions and is called NUTS-X.
[6] When this chapter was written, the tourism model was not yet fully developed and integrated into the modelling framework.

to land use, using conversion factors calibrated to data for France, Denmark and Belgium.

3.7 Spatial disaggregation of land use: DYNA-CLUE

NEMESIS provides future land use claims at the country level while some of the sector models work at NUTS-X level. In order to (i) bridge the gap between the outputs of NEMESIS and the input requirements of CAPRI and EFISCEN, and (ii) to provide more detailed land cover information for the computation of sustainability impact indicators, SENSOR uses a model named DYNA-CLUE. DYNA-CLUE disaggregates the land use claims to a one by one kilometer grid, and also allows the incorporation of spatial policies such as Natura2000 and the Less Favoured Area schemes.

DYNA-CLUE is a dynamic model with annual time steps, which distributes the land use on member state level given by NEMESIS to a 1 km resolution grid for 16 land cover types. The mechanisms of land use allocation included in the model can be divided in *location characteristic* and *conversion characteristic*. The location characteristic mechanism captures the suitability for each land use on each spot, and contains biophysical and socio-economic factors, and policy and neighbourhood effects (Verburg et al. 2004). Conversion characteristics are divided into conversion elasticities, determining the resistance of a land use type to change location, and transition sequences. A transition sequence is a set of rules that determine the possible land use conversions. Not all land use changes are possible and many land use conversions follow a certain sequence. For example, grassland cannot change into mature forest within a year. In the transition sequence it can be defined that grasslands first turn into regenerating forest after which it can change into mature forest after a certain time.

4 Principles of model linking

4.1 Upstream and downstream linkages

The models need to be linked in order to obtain a consistent simulation and to exploit the strengths of each model. This requires *upstream* as well as *downstream* linkages, because on the one hand, macro policies and interactions are only implemented in NEMESIS. Their effects must thus be communicated *downstream* to the sector models in order to capture the effects on the individual sectors. On the other hand, sector specific behaviours, for example impacts of the common agricultural policy, are only implemented in the sector models. In order to compute the effects of such policies on other sectors and the economy as a whole, the sector models must also communicate *upstream* to the macro level, where the effects can again be distributed to all sectors. The latter link is also required in order to obtain a consistent reaction of *all sectors simultaneously* to macro economic changes. Thus, bi-directional linkages are required. Böhringer and Rutherford (2006), linking a Computable General Equilibrium (CGE) model to a Partial Equilibrium (PE) model, termed this kind of bidirectional link "a combination of top-down and bottom-up".

The *ultimate* link would be to *include* the sector models inside NEMESIS and solve them simultaneously. This solution has been chosen for the models SICK, TIM and B&B. Those models can thus be considered parts of NEMESIS, and are left out in the following exposition. The remaining models NEMESIS, CAPRI, DYNA-CLUE and EFISCEN cannot, for technical reasons, be integrated in one equation system. They are implemented in different software packages, in different forms (dual vs. primal[7]) and also require advanced numerical techniques to solve already as stand-alone applications. Instead of a simultaneous solution, an iterative recalibration solution for the linked system was opted for, similar to that which links the CAPRI supply and demand modules (Britz, ed. 2005) and also to that described by Grant, Hertel and Rutherford (2006). The remaining part of this chapter is devoted to the iterative linkage of models.

4.2 Considerations for the baseline calibration

Before discussing the linkages of the models, it is useful to consider the problem of generating a consistent baseline. A baseline is a simulation outcome that is used as a reference to evaluate other simulation outcomes (Kuhlman, 2008). In an ideal situation, the models would rely on identical drivers[8], contain equivalent assumptions and yield identical baseline forecasts for items that are common to the models. For example, the agricultural sector in NEMESIS would develop exactly as the aggregate agricultural sector in CAPRI. In practice, the models are so different, including different functional forms, starting data, spatial detail, and a multitude of assumptions and auxiliary data sources, that a fully consistent baseline pro-

[7] The dual approach gives a more indirect technology representation e.g. through an econometrically estimated cost function. The primal approach allows for a physical and explicit input-output technology description.

[8] By "drivers" we mean the exogenous factors which cause the model solutions to change from the base year (e.g. 2002 in the case of CAPRI) to the target year (2025)..

jection may not be possible to obtain. In fact, the different modelling assumptions are one of the main reasons for linking the models in the first place, and we would be quite surprised to find that the same results can be obtained in two conceptually different models. The baseline calibration problem is thus to devise a way of calibrating the linked system of models so that simulation of the baseline policy scenario also delivers a stable solution. That is, if the linked system is properly calibrated to a baseline, then the information communicated through any link is such that it causes the model on the other end of the link to produce precisely the baseline.

On the one extreme, the models could be forced to reproduce fully identical solutions. We call this[9] the *harmonization approach*. For reasons indicated above, full harmonization is not feasible in all cases. On the other extreme, the difference between the models could be accepted and interpreted as differences in definition of the underlying data and assumptions. In the latter case, the ratio between the linked items (here termed the *link ratio*) is computed in the baseline and maintained in simulations. We call this the *differential approach*. The differential approach is easy to implement, and can be used in combination with harmonization. It is, however, not desirable to choose the differential approach for all positions, since that would obscure true data problems and errors.

The chosen solution is a composite of both extremes, including both adjustments of the models to harmonize baselines and "freezing" of remaining differences. For NEMESIS, a baseline calibration program was developed that treats the agricultural production and prices as exogenous, given by the CAPRI baseline, and adjusts parameters of price, domestic demand, imports and exports equations so that the aggregated results of agricultural supply and demand coming from CAPRI are nearly perfectly recovered.

Several outputs of NEMESIS and DYNA-CLUE (see below) are exogenous in CAPRI. Nevertheless, it is difficult to use those outputs directly and fully harmonize the CAPRI database with NEMESIS and DYNA-CLUE: Firstly, CAPRI is an internally fully consistent system where it is difficult to change only one item, like one price or land availability, without influencing all other items in the model about which neither NEMESIS nor DYNA-CLUE provides any information. For example, changing the land use to reflect exactly the outcome of DYNA-CLUE would make the whole market balance of agricultural products in the baseline invalid. Secondly, adopting the outputs from NEMESIS and DYNA-CLUE straightaway, thus *changing* the CAPRI results, would be fed back to NEMESIS

[9] We are not familiar with any publication that treats the general problem of calibrating a linked system of models. The terms used here, i.e. “harmonization” and “differential”, were introduced to fill the gap.

(agricultural production and prices), thus *again* changing the inputs into CAPRI upon which the baseline was based. The hence-created circular flow may be difficult to break. Thirdly, there are also many cases where the level of aggregation is different, with CAPRI being more disaggregated than NEMESIS and DYNA-CLUE (in the sense of distinguishing more different land uses). Thus, for CAPRI, the differential approach for baseline calibration is opted for, which implies computing the link ratio between the pairs of linked variables in the baseline, and then using that ratio in simulations to translate a change in the foreign variable to a change in the linked CAPRI item.

For DYNA-CLUE, a similar differential approach is used. The land use statistics that NEMESIS uses (derived from EUROSTAT) do not always match the land cover data that serves as input to the DYNA-CLUE model (derived from CORINE). DYNA-CLUE therefore only takes the annual *changes* in land use areas from NEMESIS, and imposes these changes, corrected for an 8% land cover inefficiency factor due to infrastructure, parcel boundaries etc., to the land cover map. EFISCEN, finally, needs no special calibration procedure, since there is no overlap between the outcomes of EFISCEN and any of the other models.

4.3 Iterative solution of the linked models

The preceding section discussed some problems concerning how to obtain a calibrated baseline to which all subsequent simulations can be compared. In this section we treat the problems of devising proper linkages between the different models and finding a method for obtaining a joint solution to the whole linked system in any simulation. In principle, linkages between the models are established by for each model taking certain outputs (linked items) of the other models as given inputs. A solution is obtained by repeatedly solving the sequence of models, each time updating the linked items, until convergence is achieved. Issues as to whether a joint equilibrium exists and sufficient conditions for finding it in this way are beyond the scope of this chapter, where we focus on a description of the linkages.

The links need to be implemented in the macro model NEMESIS in a way that is qualitatively different compared to the specialised models DYNA-CLUE, CAPRI and EFISCEN. The latter models need only to take the values from NEMESIS as given, exogenous data, multiplied by the link ratio of the baseline. The upstream link, from a sector to a macro model, must be handled differently. Specifically, this is the case for the link from CAPRI into NEMESIS. In this case, NEMESIS already possesses an agricultural sector, which, in the context of SENSOR, is useful to consider an approximation to CAPRI. The ultimate objective of the link is to adjust the agricultural equations of NEMESIS in such a way that they make a perfect approximation to the aggregate behaviour of CAPRI in a small area around the equilibrium solution. In SENSOR we are satisfied with a *point approximation*, i.e. to shift the functions in NEMESIS so that they run through the *point* which would result if CAPRI could have been fully included in NEMESIS (but ignoring the slope of the functions in that point).

The authors are aware of only few formal treatments in the literature of the problem of linking models. Grant, Hertel and Rutherford (2006), Böhringer and Rutherford (2006) and Rausch and Rutherford (2007) note that the linked system generally is a mixed complementarity problem (MCP), and implement what may be called Newton-Josephy-like iterative recalibration methods to solve it. This is also, in a wider sense, the approach used in SENSOR. A principal difference to e.g. Böhringer and Rutherford, who link a Computable General Equilibrium (CGE) model to a Partial Equilibrium (PE) model, is that where they remove the relevant equations from the CGE and replace them by first order approximations of the PE (i.e. linear functions that not only go through the same point as, but also have the same slope as the PE model), we keep the original equations in place and instead re-compute their parameters to obtain a point approximation. The advantage of the first order approximation would be faster convergence, whereas our approach requires less modifications of existing model code and ultimately leads to the same solution.

Under some circumstances, the iterating system will not converge. That may happen, for example, if a linked demand schedule is close to vertical and/or the slope of the corresponding supply function very big, and/or the initial shock is extreme (implying a solution out of technical bounds). In such cases, some other/additional mechanism is required in order to find the equilibrium. One such mechanism is to work with partial adjustments[10]. If partial adjustment is implemented in the sector model for, say, a price p that comes from upstream, then we use the weighted average price

$$p^i = \sum_{j=1}^{i-1} a_j p^{i-j} \qquad (1)$$

[10] Partial adjustments in the sense that only a fraction of the current solution of the macro model is going into the new parameters of the partial model. Alternatively, this could be expressed as a "lagged expectation" in the partial model, though that term is loaded with too much economic content and suggests a misleading interpretation of iterations as "time".

where a_j are weights that sum to one and indices (i,j) are iterations. For example, choosing $a_1 = 0.5$, $a_2 = 0.5$ and $a_j = 0$ for all $j \neq 1$ or 2, implies taking the simple average of the last two iterations.

Both convergence methods – the iterative approximations and the partial adjustments – may be used simultaneously, and are then capable of handling a great range of possible situations. This is done in SENSOR, with $a_1 = 0.6$, $a_2 = 0.4$, and approximations of CAPRI inside NEMESIS by a combination of non-linear functions (land demand in agriculture) and constants (total production and demand in agriculture, price index of agriculture). The iterative solution of the models, including convergence promoting extensions and computation of measures of convergence, should – in view of the immense computation time required – be fully automated. It does unfortunately not fit within the scope of this text to treat technical solutions to automation of the models.

5 Model linkages in SENSOR

Figure 2 shows how the model components NEMESIS, DYNA-CLUE, CAPRI, and EFISCEN are linked. The description of the iterative linkages can start with any of the models in the chain. In practice, the chain starts with CAPRI, since CAPRI assumes the role of controlling the whole chain. For didactic reasons, we start the description with NEMESIS.

NEMESIS determines the land use by sector according to the scheme described in section 2 and in the NEMESIS model description. The resulting land allocation for each of the sectors, on member state level, is denoted by the vector A, and is sent to DYNA-CLUE. DYNA-CLUE disaggregates the land use down to 1 km² grid units, and adds the land cover types recently abandoned arable land, recently abandoned grassland, (semi)natural cover, forests and stable areas. It also distinguishes permanent crops from rotational crops. It then re-aggregates to sub national regions: the land available for agriculture A_a on NUTS-X level, including fallow land, is passed on to CAPRI, and forest area A_f is sent to EFISCEN (for each EFISCEN region).

CAPRI also receives, directly from NEMESIS, the vector of input price indices W, technical progress index vector T, and consumer expenditure vector Y. CAPRI uses those together with the agricultural land amount A_a to compute a new set of parameters, i.e. to create a new set of input prices, consumer expenditure and land constraints.

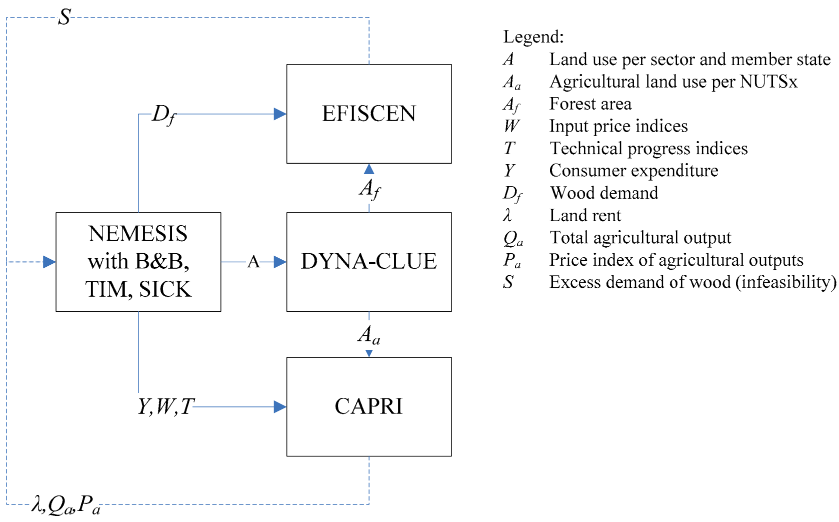

Fig. 2. Flow chart of model linkages. B&B, TIM and SICK are included in NEMESIS.

CAPRI also receives, directly from NEMESIS, the vector of input price indices W, technical progress index vector T, and consumer expenditure vector Y. CAPRI uses those together with the agricultural land amount A_a to compute a new set of parameters, i.e. to create a new set of input prices, consumer expenditure and land constraints. This implies shifting the CAPRI input prices, GDP and land constraints from the baseline values in proportion to the changes in the NEMESIS and DYNA-CLUE results. The coefficients of proportionality are computed in a differential baseline calibration approach and are referred to above as "link ratios". CAPRI also implements a partial adjustment mechanism, with two lags and the factors 0.6 and 0.4 as described in the previous section, to safeguard against rare cases where the shocks between subsequent iterations are too big. After finding a new solution, CAPRI aggregates the dual values for land λ to the member state level, and also computes gross production of agriculture Q_a and the Laspeyre's price index of agriculture P_a, and sends this back to NEMESIS.

EFISCEN receives national demand for wood D_f, from NEMESIS and forest area A_f from DYNA-CLUE. D_f is converted into physical units and from A_f changes in forest area are calculated, which are added or subtracted from the forest area in EFISCEN. EFISCEN then assesses whether the demand for wood can be satisfied and projects forest resource development. A feedback (S) is sent from EFISCEN to NEMESIS as a percentage deviation between D_f from NEMESIS and the wood removals by EFISCEN at the national level. NEMESIS uses these results from EFISCEN to constrain D_f so that it cannot exceed the demand for which EFISCEN was run. In this way NEMESIS and EFISCEN do not need to iterate. The cost of wood production may change and NEMESIS calculates a new balance between imports and exports of wood within the EU and new values for net imports outside the EU. All wood that cannot be harvested according to EFISCEN, will be imported from outside the EU.

NEMESIS uses the information from CAPRI, i.e. the land price (λ), total output of agriculture (Q_a) and agricultural price index (P_a) to recalibrate the land demand function for agriculture, and also replaces its equations for total agricultural output and one price equation by *constants* corresponding to the results (Q_a,P_a) from CAPRI. The land demand function for agriculture in NEMESIS is determined by equation (2) below[11], where, for each iteration i, λ^i is the land price, C^i_{others} an index of other agricultural inputs cost, A^i is the land demand for agriculture and c^i and b are parameters.

$$A^i = c^i \left(\frac{C^i_{\text{others}}}{\lambda^i} \right)^b \qquad (2)$$

Agricultural land prices per country (λ) are endogenous variables in CAPRI and NEMESIS and an iterative procedure is necessary to find the joint equilibrium land price in CAPRI and NEMESIS. When NEMESIS begins iteration i, the land demand is shifted in such a way that, if considered alone, at the land demand (A) and others inputs cost (C_{others}) sent to CAPRI in iteration $i - 1$, it would have returned the actual CAPRI land rent in iteration i. This implies computing c^i as shown in equation (3):

$$c^i = A_a^{i-1} \left(\frac{C^{i-1}_{\text{others}}}{\lambda^i} \right)^{-b} \qquad (3)$$

[11] In fact, the land demand function in NEMESIS is more complex, because NEMESIS is a dynamic model. The variable A denotes the long term desired level of land, and it enters with a time index in another equation with partial adjustment from period t-1.

NEMESIS is then solved including the re-calculated parameter c^i (see equation 3) in equation (2), with agricultural output and price index fixed to the last solution of CAPRI.

We conclude this section with some words about the technical implementation: In practice, the different models run on different institutes and are implemented in different software. Data exchange takes place in the form of files written to an FTP-server on the internet. The models regularly check the server to determine if a simulation is required, and in that case, download the output of the other models, recomputed parameters, simulate, and upload the new results. In that way, the rather time consuming computations can proceed with very little human intervention. In general, convergence in one simulation is achieved within a handful of iterations. Since CAPRI and NEMESIS presently both require about an hour for each iteration, and DYNA-CLUE much more, a typical simulation requires about a day of computation time.

6 Discussion

In SENSOR, a general method was developed that in theory seems capable of linking five sector models, one macro model and a land cover disaggregation model in a consistent way. In practice, not all components of a theoretically sound linkage could be established. Whereas it appears to be theoretically possible to link all variables where there is an overlap between models' outputs or where the output of one model serves as input in another, only a handful of such links could be implemented within the present project. In particular, linkages of prices of labour and capital, external trade, and the input structure of agriculture are still absent. Below we explain why these linkages are absent, and what could possibly be done about it in the future.

Prices of labour and capital are endogenous in NEMESIS, whereas they are only implicitly present in the parameters of CAPRI. CAPRI does not have labour and capital as explicit inputs, but works with gross value added. Furthermore, CAPRI uses a method derived from Positive Mathematical Programming (see e.g. Howitt 1995) to calibrate the agricultural supply module to observations and to impose a realistic supply behaviour. The calibration method together with the lack of labour and capital in the model implies that the costs for labour and capital are embedded in a lump sum costs term, which is really a behavioural term also containing all other factors influencing producer supply behaviour. To properly link the models, this cost term should be shifted, so as to reflect changes of prices of labour and capital in NEMESIS. Since labour and capital uses are not explicit in CAPRI, the size of the possible error is difficult to assess.

Both NEMESIS and CAPRI feature endogenous external trade. Since CAPRI has a comparatively sophisticated trade model, the external trade of agriculture in NEMESIS should be linked with that in CAPRI. This has not been done, and the differences in external trade between CAPRI and NEMESIS can now serve as a "quality measurement" of the linkage. Due to the time constraints in the project, this has not been done.

Finally, CAPRI contains a much more detailed technology of agriculture than NEMESIS, and is thus capable of delivering more precise forecasts of changes in inputs. Use of inputs by the agricultural sector is endogenous in NEMESIS and information from CAPRI is presently not exploited in NEMESIS. Similar to the case of external trade, the difference in agricultural input use between the models could be (but have not been) evaluated ex-post in order to assess the size of the possible error.

7 Summary

This chapter described the coupling of five sectoral models to one macroeconomic model and one land cover model. Linking these models allows for a consistent, multi-scale and multi-sectoral assessment of important land use change processes. Though not a fully theory-consistent link could be implemented in SENSOR, the system still provides significantly extended capabilities compared to the stand-alone models. Most importantly, the system captures the essential ingredients of the competition for land by different sectors. Policies that are directed towards any individual sector inevitably affect the regional land balance, and thus all other land-based sectors. However, land balances are not the only links implemented in the SENSOR modelling approach. Other linkages are e.g. between CAPRI and NEMESIS input prices and GDP (see Figure 2). With the linked system presented here, the impact at sector level of general economic policies and developments can be analysed. Hence, analysis of, for example the simultaneous impact of bio-energy policies on the energy using and producing sectors inside NEMESIS, wood removals and forest resource development in EFISCEN and agricultural production in CAPRI, becomes possible. Another important property of the system is the possibility to link sector policies to national innovation policies. In one SENSOR scenario, namely financial reform of the common agricultural policy (CAP), this strength is utilized to obtain improved measures of and insights into the opportunity costs of the CAP by analysing the effects of transferring funds now spent on agricultural support to national innovation (R&D) policies, and assessing the impact on national income, rural land use and agricultural income. Who will gain from such a transfer, who will lose and what will be the overall impact on the economy, are questions that can be analysed with the model system. Last but not least, the process of developing the system has lead to accumulation of new insights in the principles of model linking, which may prove beneficial not only to SENSOR but also in a wider perspective.

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Tourism geography in Europe

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Abstract

In the tourism component of SENSOR, attraction modelling is needed to predict the likely distribution of growth in tourism facilities at the sub-national level. Modelling of tourism flows between countries is obtained through a demand modelling linked to a bilateral flow matrix. This paper presents analysis of tourist beds at the NUTSX level in order to allow for a geographical disaggregation of tourism loads within the country. In summary, 79% of the variation in tourism bed densities and 39% of the variation in growth through the 1990s can be explained by physio-geographical predictors in combination with GDP/capita and population. Prominent predictors of tourist attraction are the relatively ‘fixed assets’ of alpine areas in the region and access to the coast, but several variables also link the attraction modelling to other model outcomes from the SENSOR project. Population density, GDP/capita, urban and nature land cover are generally positively related to tourism loads, while agriculture is negatively related to tourism. Thus, the regression models presented in the paper can be used to estimate the attractiveness of regions to tourists in a way that will be sensitive to the scenarios specified in the SENSOR project. Furthermore, the regression results suggest the magnitude of a saturation tendency, implying that crowding at some destinations will gradually redistribute tourist to other regions within the country.

Keywords

Europe, tourism, tourist beds, attractiveness, statistical analysis

1 Introduction

Tourism is a significant factor contributing to economic, social and environmental changes, positive and negative, in the regions visited. Around 60% of world-wide tourism takes place in Europe, and tourism to Europe is growing rapidly. From an estimated 443.9 million international tourist arrivals in Europe in 2005 (UNWTO 2006), the number of arrivals is predicted to reach 717 million in 2020 (WTO 2001). These figures do not include the high number of domestic tourists travelling within their own country. In 2002 – within the EU-15 alone - there were 1,507 million overnight stays by tourists, of which 939 million stays were by domestic tourists (62%) and 568 million by international tourists (38%) (Eurostat 2006). Tourism in the EU is primarily driven by intra-EU-25 tourist flows. Domestic tourists account for 59% of tourist overnight stays and 32% are other EU-25 tourists, while only 9% come from outside the EU-25 (CEC & Eurostat 2006a).

An immediate spatial impact of tourism is derived from the tourists' demands for facilities, including infrastructure and overnight accommodation. In 2004, the EU-25 had a capacity of approximately 24.4 million tourist bed places (Eurostat 2006a), and the number of beds is growing. In addition, well over 10 million second homes are located within EU-25. The second homes are generally not included in statistics on tourism, which focus solely on "collective establishments". The facilities for tourists are spatially encroaching on other land uses. Statistical sources do not include explicit data on the land appropriated for tourism facilities, and it must be assumed that tourists take up a proportion of urban land uses and therefore contribute to urban growth and sprawl (EEA 2006), depending upon the regional context.

The tourism modelling of the SENSOR project includes a number of steps and sub-models (see chapter 8 for an overview of the modeling framework). In the demand modeling, an economic model linked to a tourism demand model predicts the flows of tourists between the European countries in response to general price levels and transport prices in particular. However, the demand model predicts changes only at the national level, and a more detailed evaluation of the likely spatial impacts of tourism under different scenarios, requires a tool for geographical allocation of inbound tourists at the sub-national level. The goal of this chapter is to develop such a tool based on the tourism attraction factors.

Objectives

The objective of the modeling exercise is to identify key tourism attraction factors – based on available European and global data sets - which can explain the geographical distribution of tourists in European regions. The regions used for the analysis are the so-called NUTSX regions, constructed for use in the SENSOR project. The NUTSX regions combine existing NUTS2 and NUTS3 regions to arrive at a more comparable size for the regions across Europe, and thus overcome some of the analytical problems related to the diversity in size between underlying geo-statistical units.

Key questions

The main questions which the model addresses are the following:

> *What are the determinants of the geographical distribution of tourism loads in Europe? How far can we determine these factors by using available European statistics on physio-geographical aspects, such as land-use, climate, location and accessibility?*
> *Are there significant saturation effects for tourism growth at the level of NUTSX regions?*

Limitations

The limited availability of data below country level forms an important part of the premise for the analysis. In the cross-sectional analysis, an extensive range of available data at the NUTSX-level will be assembled in an attempt to explain the geography of European tourism. The lack of suitable variables especially affects the analysis of the development in tourism over time. Very few data for the development over time is available at the level of the NUTSX zones – used in the SENSOR project – and in the present analysis.

2 Background

The current distribution of tourists is highly uneven, as some regions of the EU are more especially attractive to tourists. A diversity of motives and attractors influence the selection of tourist destinations. This is the result of highly complex psychological motives and social and economic factors forming the demand for tourism, as well as the supply of a variety of tourism opportunities meeting these demands. Despite tourists' highly individual motives and preferences, the tourism patterns across Europe remain oriented towards certain regions – attributes of these regions appear to be more attractive to tourists than those of other regions – but what are the attractors?

2.1 Travel motives

The motives for travelling are very complex and differ from person to person in response to their underlying psychological needs and constraints. In general, we distinguish between push factors – the factors (e.g. employment, community, and personal life) motivating people to travel away from their home, and pull-factors – the factors in the receiving regions attracting people to choose certain destinations they find attractive in meeting their underlying needs (WTO 1997).

The motives for travelling vary with many factors, such as age, sex, stage in the family life-cycle stage, personality, interests, etc. Previous travel experience also plays a role, as people tend to have different motives as they get more experienced according to the Travel Career Ladder (Pearce 1988, 1991).

According to the theory of ritual inversion (Graburn 1983), tourists going on holiday often seek some level of contrasts to their everyday life and home environment. The theory suggests in their choices and activities, tourists may select places and activities which are opposites of those experienced in their home environment. However, each type of tourism only involves a few key reversals. The amount and type of contrasts vary by several factors, including the tourist's tendency toward more adventurous or safety-oriented experiences, which reflect their different personality types (Plog 1974). Examples of contrast-seeking related to the natural environment may include Northern Europeans seeking the warm and sunny Southern European climate or land-locked Central Europeans seeking the wide-open coastal areas and beaches, or the Dutch seeking the hilly or mountainous areas for vacation as a contrast to their own lowlands. Some landscape features (e.g. sandy coastal beaches) are attractive to most people as they represent the classical images of a holiday. All in all, the choice of tourist destination relies on a wide range of factors of which only some are related to the actual landscape features.

2.2 Studies of travel motives

A large number of studies address tourist demand models (e.g. Crouch 1995, Hu & Ritchie 1993, Klenosky 2002, Lim 1995, Lohmann & Kaim 1999, Papatheodorou 2001, Pike 2002, Seddighi & Theocharous 2002, Witt and Witt 1995). But almost all studies focus on economic and demographic factors of the countries of origin of tourists and provide little input to identify relevant destination attributes to include in the study.

Almost all models attempting to explain tourism flows focus on the demand side – the background factors in the tourists' country of origin stimulating or limiting their propensity to travel. But while this is part of the equation, the pull factors of the destination attracting tourists to visit – the supply side - seems to be largely ignored.

A study by Zhang & Jensen (2007) analyses tourism flows from a supply-side perspective based on new theories of international trade. The attraction factors they include to explain tourist arrivals are: receipts, population, GDP per capita, hotel capacity, FDIHR (foreign direct investment in hotel and restaurant sector), the stock of foreign direct investment, openness (of export and import), PPP (relative price level of the destination), and a time trend. Furthermore, a country-specific variable is used to cover the cultural and natural attractions, including climate and scenic advantages.

Results show that the fixed country-specific effects that capture natural endowments are highly significant. Countries compete for tourist arrivals on the basis of natural endowment. In a world-wide context, however, this competition is more between countries from different world regions than between countries from the same region. Advantageous natural endowments between countries of the same region matter only among the OECD and the Middle East countries. This means that some OECD countries rely extensively on the country-specific factors, such as scenic attraction and cultural heritage, as a basis of comparative advantage to distinguish their tourism product, whereas other countries do not. The higher relevance of country-specific factors within the OECD may be explained by the majority of tourists emanating from the OECD countries and having a better appreciation of the underlying cultural and heritage endowments of their own countries as compared to countries in more distant regions.

The results render strong support for the relevance of certain supply-side factors in explaining international tourism flows, such as natural endowments, as well as created assets associated with technology, infrastructure and international knowledge spill-over. Interestingly, price competitiveness is not found to be a robust variable. Within the OECD area, prices play the reverse role – higher prices attract more tourists. This is explained by these countries having been able to differentiate and augment the tourism product that they offer.

Unfortunately, the highly important country-specific effects identified in their study are not further explored by Zhang & Jensen (2007). The supply-side factors discussed in their study are largely economic. More detailed identification of key destination attributes is the focus of the present study, but only within the EU-region.

2.3 Destination attributes

A few empirical studies touch on the issue of destinations and their attributes. A 1997-98 Eurobarometer survey (CEC, 1998) included data on which type of destinations tourists from the EU-15 countries choose. Sixty-three percent of European holiday makers choose the sea, 25% the mountains, 25% the cities and 23% the countryside. National differences were found for most factors as well as socio-demographic differences.

A study of travel motives and vacation activities of 55,.000 tourists in 15 European countries (Danmarks Turistråd 1999) included a few pull motives. The natural features of the destination were valued highly by all nationalities: Experiencing nature was highly important or important to between 65-80% of the tourists – particularly Danes, Poles and Italians, while Swedes and Norwegians were the least interested (having vast expanses of wilderness at home). Visiting undisturbed areas was either important or highly important for between 25-57%, with the French, Italian, and British tourists being most interested, while the Swedes and Norwegians were the least interested. The quality of the environment was also included in the survey. Here 45-78% found it important or highly important to visit places with clean air and water – especially the Poles, Italians, French, and British tourists. Furthermore, 11-57% found it important or highly important to visit places caring for the environment – the Germans viewed this factor as especially important.

A few pull-motives related to climate were also included: Enjoying the sun/getting a suntan were important or highly important to between 47-68% of the respondents – though not particularly those from Northern Europe. Experiencing a different climate was important or highly important to between 40-65%. Here the tourists from Southern Europe tended to be a bit more interested than tourists from other European countries with more shifting weather conditions. This may reflect the desire oft many Southern Europeans for cooler climates during the hot summer season.

The cultural and historic attractions were also included: Visiting historic places was important or highly important to between 39-58% with smaller national differences. Cultural experiences were important or highly important to 25-50%, and particularly the Germans an Italians were interested in these attractions. However, although some national differences are found for most factors, no clearly consistent pattern emerges from this data.

3 Data and methodology

This section presents the data used for the analysis of tourism loads in European regions as well as the methodology employed in the analysis and specification of tourism predictors. The section describes dependent variables, independent variables, and the overall methodology.

3.1 Dependent variables

The dependent variables consist of the only tourism indicator available at NUTS3 level from EUROSTAT with a reasonable coverage of European space, namely the number of tourist beds.

Data at the NUTS3 level allows for a dataset to be aggregated to the NUTSX regions used in the SENSOR project and the present analysis. The number of tourist beds by region is available from EUROSTAT from the mid-1990s onwards. This allows for two dependent variables to be analysed: (1) density of tourist bed spaces in NUTSX regions; and (2) growth in number of tourist bed spaces in NUTSX regions.

The number of bed spaces in NUTSX regions, as used in the analysis for 2000/2001/2002 was dependent upon the variations in data-availability between the European countries. The growth-variables will represent average yearly change based on data from the period 1995/1996/1997/1998 until 2000/2001/2002, depending on the specific data that is available from the different countries.

3.2 Independent variables

The independent variables included in the analysis are presented in Tables 1 and 2. These are primarily selected from data sets with tourism relevance that have European coverage and can be aggregated to the NUTSX level. Thus, climate, landscape, land cover, nature and access to the coast are important elements, together with statistics from the EUROSTAT databases: population and GDP. Although most of the factors identified in the literature as central to tourism are represented, additional variables with information on the cultural environment and similar amenities would be desired. However, more refined analysis may be possible in the future as more data becomes available.

Table 1. Description of independent variables for use in cross-sectoral analysis

Key factor	**Operational independent variable**
Coast	Length of coastline
	Coast dummies (Mediterranean, Atlantic/English canal, other coast)
Landscape	Bio-geographical region dummies (including alpine areas/mountains)
Nature	Forest and natural land cover (%)
	Corine biotopes (sites and % of land cover)
	Sites with national designation status (sites and % of land cover)
Culture	Urban Morphological zone (%)
	MEGA-city (ESPON definition)
	Historical city (more that 1 mill. inhab. before World War II)
	World heritage sites (UNEP)
Climate	Temperature (summer and winter)
	Precipitation
Accessibility	Distance to nearest international airport
	Daily accessibility
	Potential accessibility
Population	Population density
Price levels	GDP in EURO/capita

Table 2. Description of additional independent variables for the analysis of changes in tourism loads in NUTSX regions.

Key factor	**Operational independent variable**
Tourism	Tourist density per land area, urban area or coast length
Population	Change in population density
Price levels	Change in GDP in EURO/capita

The list of explanatory variables is clearly shorter than what would have been preferred from a theoretical point of view and from the perspective of policy implications. The inclusion of strategic variables in the data set would be desirable as a link to regional policy. Such variables may be public investment in culture (presently available only at the country level) or accounts of cultural or tourism-oriented attractions such as museums, entertainment, etc. It is possible that the analysis presented in the present paper may be improved when data becomes available, e.g. as an output from the ESPON project on cultural heritage (ESPON 1.3.3, 2006). Furthermore, additional variables to represent change over time are desirable. In the present analysis, only change in population and GPD at the NUTSX level can be included. The most important 'omitted' change variable in the analysis of growth in tourist bed densities is likely to be the change in accessibility. However, lack of access to historical transportation networks makes this variable very difficult to include. The analysis presented therefore rely on measures of accessibility in the present situation (2000/2001) based on variables from the ESPON project on transport infrastructures (ESPON 1.2.1, 2004).

Within ESPON 1.2.1, analysis of accessibility was done at the NUTS 3 level with respect to daily accessibility and potential accessibility; by surface modes, air-mode and multimodal (fastest combination of modes). In this context, 'daily accessibility' refers to an assessment of the maximum travel times that would be allowed in a daily (everyday) travel budget and the number of customers or purchasing power within this (time) range. 'Potential accessibility' measures accessibility based on the number of customers or purchasing power within Europe by assuming that the travel distance has a negative impact on the likeliness of interaction taking place (distance decay). Both types of measures, together with the more simple 'distance to airport', are included in the analysis.

3.3 Methodology for analysis

The methodology for analysis can be presented as two subsequent steps that will apply to the cross-sectional analysis of tourist beds and to the analysis of change over time. These two steps are data reduction and multivariate analysis.

Step 1: Data reduction

Factor analysis is employed to reduce the number of variables and describe the main variations across European space within three sub-groups of variables. The first sub-group consists of the variables that indicate temperature and precipitation. These variables are likely to be closely correlated, and data reduction into factors is necessary before analysis proceeds. The second sub-group of variables is those that describe land use, including nature and the degree of urbanisation, in the area. As with the first two subgroups, the values on these variables are likely to be closely correlated and partly mutually exclusive. The third sub-group of variables is those that describe accessibility. The ESPON 1.2.1 project has made a range of measures available, and these will be used to extract the dimensions that vary across European space.

Especially in the context of the present study, which recognises its limitations due to the limited availability of explanatory variables besides physical and geographical data, it seems reasonable to reduce these sets of variables into the main differences across European space. In this way, we avoid the rather arbitrary results that may result from an inclusion of the variables without reduction.

Step 2: Multivariate analysis

The sets of factors derived in Step 1 are included as explanatory/independent variables in multivariate analysis of the variation in tourist densities across Europe. The remaining variables -- access to the coast, accessibility, population density, price-level proxy and possibly regional dummies (new member states, accession countries) -- will be included in parallel with factors derived in Step 1.

The multivariate analysis is carried out cross-sectional, with the tourist densities in 2001 as dependent variables, and with the change in tourist densities per year as the dependent variable. The analysis of changes in bed densities will include changes in drivers and explanatory factors over time, when available, but will otherwise rely on the more 'fixed' description of the physio-geographical properties of the regions used in the cross-sectional analysis.

4 Data reduction: factor analysis

To reduce the number of variables but also retain the relevant variations within Europe in the dataset, factor analysis in the form of Principal Component Analysis (PCA) was applied to the following subsets of variables: land cover, climate, and accessibility variables. The aim was to reduce the large number of variables within each subset to a smaller number of factors/components capturing the major differences within Europe, such that these components/factors could be subsequently incorporated into the explanatory analysis of the number of tourist beds in European NUTSX regions.

The reduction of variables into components/factors was guided by the eigenvalue criterion (a principal component should have an eigenvalue above 1), with some adjustments in the case of land use based on the interpretation of the components suggested by the analysis.

Table 3. Summary of factors (components) derived from Principal component analysis of land cover, climate and accessibility variables respectively.

LAND COVER/USE	
82% of variation in 7 variables:	Artificial surfaces; surfaces for transport infrastructure; surfaces used for agriculture; forest and nature land cover; wetlands; surface covered by Corine biotopes; and surface within the urban morphological zone (all measured in pct. of land cover within NUTSX regions)
Explained by 3 factors:	
Urban (F1)	Urban land uses vs. agriculture or nature.
Agriculture (F2)	Agriculture vs. urban or nature land cover (some blend in of wetlands in agricultural areas).
Nature (F3)	Nature areas and/or wetlands vs. urban, agriculture or forest land cover.
CLIMATE	
80% of variation in 7 variables:	Temperature at the warmest location in the region in the warmest quarter of the year; average temperature across all locations in the region in the warmest quarter of the year; temperature at the coldest location in the region in the coldest quarter of the year; average temperature across all locations in the region in the coldest quarter of the year; precipitation at the driest location in the region in the driest quarter of the year; average precipitation across all locations in the region in the driest quarter of the year; average yearly precipitation
Explained by 2 factors:	
Precipitation (F4)	Wet and temperate climate
Temperature (F5)	Warm and dry climate
ACCESSIBILITY	
73% of variation in 10 variables:	Number of commercial airports; traffic in commercial airports; driving time by car to commercial airports; driving time by car to motorway access; daily population accessible by car; daily market/GDP accessible by car; potential accessibility by air; potential accessibility by rail; potential accessibility by road; and potential multimodal accessibility.
Explained by 2 factors:	
Potential accessibility (F6)	The potential and daily accessibility, largely governed by surface modes, but with some contribution from the air-mode as well.
Access by air (F7)	Access to international airport and the level of service offered at this airport (passenger volumes).

As the main result of the principal component analysis, seven land-use variables, seven climate variables, and 10 accessibility variables are reduced into three land-use factors, two climate factors and two accessibility factors for further analysis. These factors will be used in the multivariate regression models in the next section together with the remaining ‘non-reduced’ variables (Table 3).

5 Analysis of tourist bed densities in 2001

To enhance knowledge of the correlations between the explanatory variables under control for other relevant factors, we have carried out a multivariate analysis of tourist bed densities as well as the yearly growth in bed densities (next section). This paper presents analysis based on the ‘optimal model’ approach. The optimal regression model is the model that explains the highest proportion of variation in the dependent variable with statistically significant effects and without inexplicable signs and effects (contra-intuitive effects) on the explanatory variables.

The optimal regression models, based on the data at hand, were identified based on a sequence of model searches in the SPSS statistical software. Particular attention was given to the effects of multi-colinearity between the variables and the differences in the number of missing cases, that may change the results as variables are gradually taken out of the equation (list-wise exclusion of cases was used). Gradual alterations to the subset of variables that formed the basis for model searches were applied to test the ‘robustness’ of the end result. The regression models resulting from the search can be seen in Table 4. Independent model searches were carried out for EU-25, EU-15 and the new-member countries in the eastern part of Europe (N-10 in ESPON terminology).

A cross correlation matrix for the explanatory variables included in the analysis can be seen in Table 5. Many of the variables are correlated to some degree, especially the new member state dummy and GDP/capita that display a Pearson correlation of -0.884. In the model for EU-25, these two variables were also those that were predicted to the highest degree by the other explanatory variables (Tolerance levels 0.133 and 0.152 respectively). The results for EU-15 and N-10 do, however, indicate that GDP/capita should be present in the EU-25 model. At the same time, the new member state dummy seems to be significantly partially correlated with the tourist bed density and thus allows some control within the model for the large east-west differences.

Table 4. Regression models explaining the density of tourist beds in NUTSX regions in 2001. Variables derived from factor analysis is indicated with 'F'; natural log transformations with 'LN'.

	EU25			EU15			N10		
	B	**Beta**	**Sig.**	**B**	**Beta**	**Sig.**	**B**	**Beta**	**Sig.**
(Constant)	-11,849	-	0,000	-9,232		0,000	-12,164	-	0,000
Potential accessibility (F6)	0,230	0,153	0,000	0,224	0,188	0,000	-	-	-
Urban (F1)	0,095	0,060	0,090	0,106	0,090	0,073	-	-	-
Agriculture (F2)	-0,249	-0,167	0,000	-0,191	-0,165	0,000	-0,332	-0,187	0,000
Nature (F3)	0,165	0,114	0,000	0,198	0,184	0,000	-	-	-
Alpine, pct. of land cover	0,678	0,091	0,000	1,209	0,170	0,000	-	-	-
Mediterranean coast	1,152	0,245	0,000	1,057	0,297	0,000	1,640	0,232	0,000
Atlantic coast	0,852	0,162	0,000	0,790	0,210	0,000	-	-	-
Other coast	0,460	0,099	0,000	0,345	0,100	0,011	0,970	0,137	0,001
Pop. /sq.km, 2001 (LN)	0,411	0,307	0,000	0,443	0,441	0,000	0,538	0,333	0,000
GDP/capita, 2001 (LN)	1,137	0,758	0,000	0,859	0,221	0,000	1,233	0,584	0,000
New member states (0, 1)	1,131	0,348	0,000	-	-	-	-	-	-
N=		454			312			142	
Adj. R-square		0,793			0,735			0,742	

The regression models explaining the variation in tourist bed densities in 2001 in EU-25 and EU-15 (Table 4) contain a large share of the variables that formed the basis for model searches. Tourist beds are positively related to potential accessibility, indicating that the more accessible regions have higher tourist densities.

The three land cover factors indicate that the degree of 'urban-ness' and the presence of nature areas attract tourists, while agricultural land uses are negatively correlated with tourist bed densities.

Furthermore, the percentage of land cover in the Alpine biogeographical region and the three variables indicating access to the coast are all positively related to tourist bed densities. The effect of Alpine land cover is likely to receive a large part of its influence from ski tourism, with some added value from the characteristics of the landscape and the contrast to the rest of Europe.

Access to the coast is clearly a very important feature of attractiveness in the regression models. The Mediterranean coast appears as the most attractive coast (the most important variables among the coast-variables) followed by the Atlantic coast and the English canal, and the other coasts of Europe.

Table 5. Bivariate correlations (Pearsons r) between the explanatory variables included in the regression model explaining tourist bed densities in 2001 (Table 4). Correlations significant at the 5% level (two tailed test) are marked with '*'.

	Potential accessibility (F6)	Urban (F1)	Agriculture (F2)	Nature (F3)	Alpine pct. of land cover	Mediterranean coast	Atlantic coast	Other coast	Pop./km^2. 2001 (LN)	GDP/capita 2001 (LN)	New member states
Potential accessib. (F6)		0,428*	0,149*	-0,133*	-0,161*	-0,160*	-0,023	-0,096*	0,637*	0,483*	-0,346*
Urban (F1)	0,428*		0,000	0,000	-0,141*	-0,093*	-0,062	0,090*	0,728*	0,263*	-0,090*
Agriculture (F2)	0,149*	0,000	1,000	0,000	-0,384*	-0,252*	0,065	0,269*	0,012	0,031	0,018
Nature (F3)	-0,133*	0,000	0,000		-0,105*	0,108*	0,022	0,297*	0,093*	0,081	-0,085
Alpine pct. of land cover	-0,161*	-0,141*	-0,384*	-0,105*		0,066	-0,115*	-0,192*	-0,092*	-0,307*	0,252*
Mediterranean coast	-0,160*	-0,093*	-0,252*	0,108*	0,066		-0,070	-0,158*	0,028	0,027	-0,148*
Atlantic coast	-0,023	-0,062	0,065	0,022	-0,115	-0,070		-0,132	0,050	0,117	-0,187
Other coast	-0,096*	0,090*	0,269*	0,297*	-0,192*	-0,158*	-0,132*		-0,068	0,294*	-0,183*
Pop./ km^2 2001 (LN)	0,637*	0,728*	0,012	0,093*	-0,092*	0,028	0,050	-0,068		0,211*	-0,045
GDP/capita 2001 (LN)	0,483*	0,263*	0,031	0,081	-0,307*	0,027	0,117*	0,294*	0,211*		-0,884*
New member states	-0,346*	-0,090*	0,018	-0,085	0,252*	-0,148*	-0,187*	-0,183*	-0,045	-0,884*	

On the basis of the model searches, the effect of the Mediterranean coast cannot be reduced to a matter of coast and warm climate. Other aspects that could lend themselves to the effect of the variable are the character of the sea, other aspects of climate such as wind, vegetation and landscape, and most likely the (historical) position of the Mediterranean on the mental map of northern European tourists.

Population density and wealth measured as GDP/capita are both positively related to tourist bed densities. Both variables can be explained as a general relationship between the level of activity in the region and how this affects the development of the tourism sector, as well as the overall attractiveness and visibility of the region.

GDP/capita is the most important variable (based on beta coefficients) in the model for EU-25, but GDP/capita only ranks third within the EU-15 group. The use of the variable GDP/capita in the models is likely to introduce some endogenity to the regression model, as GDP may be higher because there are tourists. However, it is the perception of the authors that given the rough scale of analysis and the cross-sectional approach, the GDP per capita variable is more likely to reflect a local economy that facilitates the development and expansion of tourist services among other things; and maintains relations with the outside world, and through this, improves its position as a potential destination for tourists and business travellers alike (see also Zhang and Jensen, 2007).

The prominent effect of the GDP variable in the EU-25 model, which also includes a dummy variable for new member states, can be interpreted as being in favour of seeing the GDP pr. capita as a signifier of the state of the economy; the development of competitive tourist services/facilities; and the integration into a wider European market (yielding more comparable economic results).

Among the new member states of the European region: GDP/capita is the most important explanatory variable; followed by population density and the Mediterranean coast.

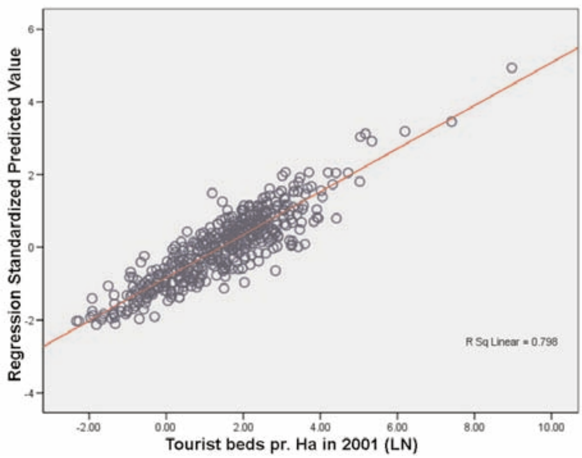

Fig. 1. Plot of standardized predicted values as a function of tourist beds pr. ha.

This probably also reflects a pattern where the development of tourism is focused mainly on the largest cities, or on a limited number of nodes on the coast.

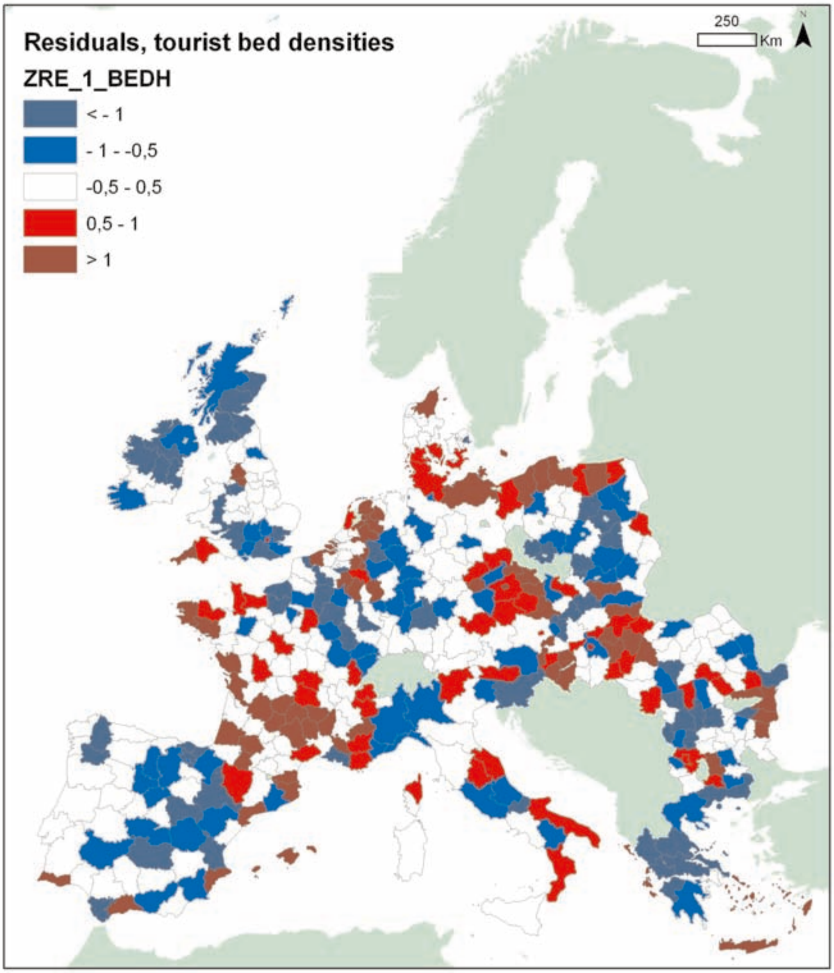

Fig.2. Standardised residuals by NUTSX region.

The overall fit between the predicted tourist bed densities and observed, empirical bed densities for EU-25 is indicated in Figures 1 and 2. The plot of predicted densities against observed bed densities displays a generally linear form, with a regular dispersal on both sides of the regression line (error-term). Thus, the linear regression model seems to be a most appropriate representation of the variation in the data. The map of residuals (difference between observed and predicted bed densities) in Figure 2 indicates that there are no severe spatial biases, country biases or the like in the result. There are some regional clusters of biases that indicate that the analysis could be improved through the inclusion of more variables and if nothing else through the inclusion of dummy variables. These are: NUTSX regions on the southern shore of the Baltic Sea, and the French ‘Massif Central’; both have positive residuals and Greece has negative residuals.

6 Analysis of growth in tourist bed densities, 1994-2001

Growth within the relatively short time period covered by the EUROSTAT data on tourist beds is considerably harder to explain statistically than the distribution of bed densities in the status quo condition. Different specifications of the dependent variables were tested: growth in absolute numbers, relative growth, growth in beds pr. inhabitant; growth in beds pr. capita, etc. However, no substantial differences were found with respect to the level of explanation that could be achieved or the theoretical preconditions for linear regression analysis. This section presents the results for relative growth in tourist bed density (Table 5).

There are differences in comparison with the regression models explaining tourist bed densities in 2001. Where no significant correlation with climate is found in the ‘status quo’ models, there is a strong positive correlation between growth in tourist beds and warm climate, and a corresponding negative correlation between precipitation and tourist beds. Furthermore, there is no significant correlation between growth in tourist densities and access to the Mediterranean coast. Thus, the results indicate that the European tourism geography is changing: there is a shift from wet and temperate regions towards warm and dry regions; at the same time, there is a reduced importance of the Mediterranean coast. As a broader interpretation, the travel range of the tourists is becoming wider due to tourists’ increased wealth and mobility. This allows tourists to favour warm and dry locations in the south of Europe. At the same time, the increasing ‘footlooseness’ of tourists is allowing tourist services to be developed in areas that have not previously received large volumes of tourists. The increasing diversification of the tourism demand indicated by the ‘travel career ladder’ (Pearce 1988, 1991) may also form part of the explanation, as the population of Europe becomes more and more accustomed to travelling abroad.

Adding to this difference, between the model describing status quo and the model describing growth, is the negative sign on the variable tourist beds pr. square km in 1994 (the beginning of the period covered by the data). This indicates that a saturation effect may be at work. Crowding at the destination could be a disincentive; at the destination, crowding may discourage further development of tourist facilities; for the potentially inbound tourists, the crowding may cause them to choose to go somewhere else.

Potential accessibility, urban, agriculture, nature, alpine areas and growth in population density also add to the explanation and prediction of growth in tourist bed densities. For these variables, the signs (+/-) were the same as what was found in the model of tourist beds densities in 2001. A dominance of agricultural land uses was negatively correlated with tourism growth, while the other variables were positively correlated. It is remarkable that the agricultural land uses appeared to be the second most important variable within the regression model explaining tourism growth (Beta= - 0,270).

Table 6. Optimal multivariate regression models explaining relative growth p.a. in tourist bed densities, between 1994 and 2001. Version 1 include the variable "Coast – but not Mediterranean" while version 2 omits this variable. Variables derived from factor analysis is indicated with 'F'; natural log transformations with 'LN'.

	Beds/Ha pct. growth p.a. 1994-2001					
	Version 1			**Version 2**		
	B	**Beta**	**Sig.**	**B**	**Beta**	**Sig.**
(Constant)	-2,324		0,021	-2,739		0,006
Potential accessibility (F6)	0,016	0,169	0,019	-	-	-
Precipitation (F4)	-0,023	-0,212	0,000	-0,015	-0,143	0,007
Temperature (F5)	0,033	0,245	0,000	0,016	0,122	0,018
Urban (F1)	0,025	0,243	0,000	0,024	0,247	0,000
Agriculture (F2)	-0,025	-0,270	0,000	-0,023	-0,251	0,000
Nature (F3)	0,009	0,107	0,039	0,007	0,087	0,078
Alpine, pct. of land cover	0,121	0,214	0,001	0,017	0,142	0,004
Coast – but not Mediterranean	0,043	0,189	0,002	-	-	-
Pct. growth p.a. in pop/Ha (LN)	2,109	0,123	0,016	2,483	0,145	0,005
Beds/sq.km, 1994 (LN)	-0,058	-0,734	0,000	-0,050	-0,649	0,000
N=		306			308	
Adj. R-square=		0,390			0,361	

Any type of coast contributed positively to tourist bed densities in 2001, but only non-Mediterranean coasts seem to be significantly related to the growth in tourist bed densities. This effect has been assembled into one dummy variable in Table 6. As the significance of all other coasts than the Mediterranean suggests a rigid precision of the result, including the spatial allocation of tourism growth not supported by the limitations to the methodology, an attempt was made to remove this variable from the model (Table 6, version 2). This exercise also removed accessibility from the model, as it became insignificant. The level of explanation measured by R-square declined slightly, from 39% to 36%. Thus, the difference between Mediterranean coasts and other coasts adds slightly to the explanation of trends in the late 1990s.

As the availability of historical data on tourist beds from the new member states in Eastern Europe was very limited, only few cases from Eastern Europe were included in the analysis. However, no significant difference between EU-15 and N-10 countries, with respect to growth in tourist bed densities was found within the data at hand.

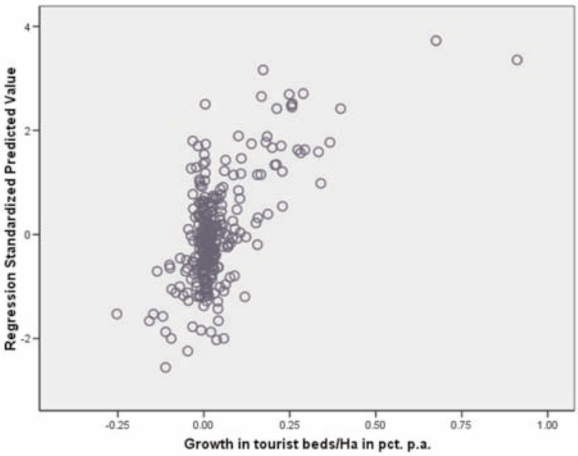

Fig. 3. Plot of standardized predicted values as a function of growth in bed densities (model: Table 6, version 1).

The plot of predicted growth against observed growth (Figure 3) reflects the differences in the ability of the regression model to predict growth in tourist bed densities. With an adjusted R-square of 0.390 for growth – compared to an adjusted R-square of 0.793 for the present status – the pattern of growth is clearly more difficult to describe and analyse statistically.

The R-square of 0.390, however, is still substantial and indicates that the results add to our knowledge of the correlates of tourism growth across Europe. With respect to the spatial distribution of the residuals, Figure 4 indicates that the negative residuals in the Mediterranean region (Portugal, Greece, Corsica, Sicily) may warrant a search for additional driver variables or alternatively, regional dummy variables. There are also generally negative residuals on the British North Sea coast and an identification of the 'British Isles' in a dummy variable could also be attempted.

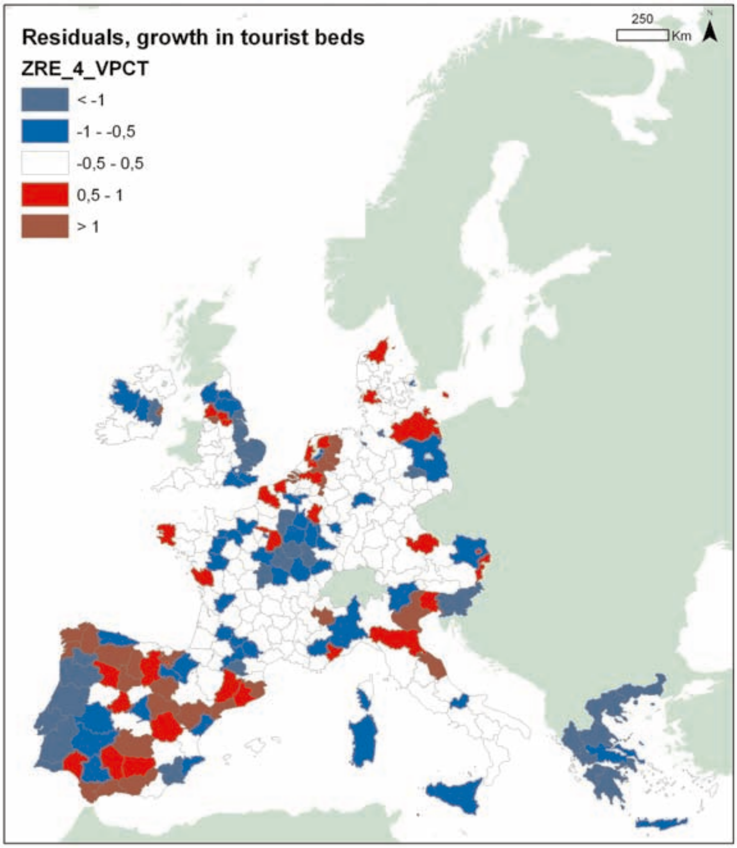

Fig. 4. : Standardized residuals by NUTSX region.

6.1 Sensitivity towards baseline and policy scenarios

The model results presented in this paper allow for the prediction of tourists by NUTSX regions in response to population, economic development and aspects of the landscape/land cover. The predicted number of tourists can also be interpreted as an index of tourist attractiveness by region that can serve the purpose of geographical distribution of nationally inbound tourists.

The map in Figure 5 shows the current tourist attractiveness predicted on the basis of the empirical data for 2001. The map in Figure 6 shows the growth in tourist bed densities through the 1990s, predicted on the basis of population growth, tourist bed density at the offset combined with land cover and other variables reflecting status quo in 2001.

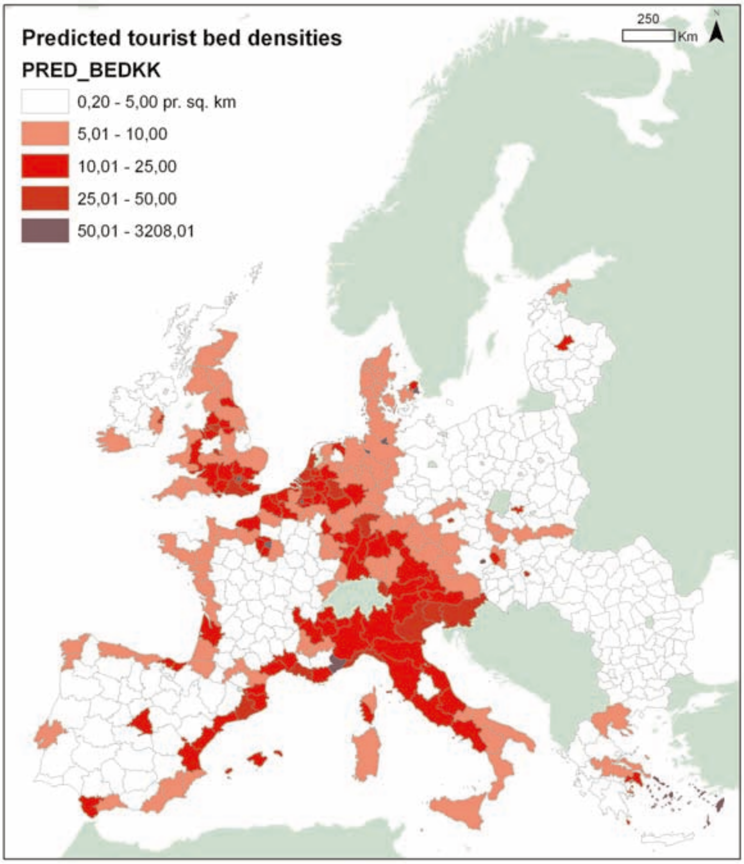

Fig. 5. predicted tourist bed densities in NUTSX region, 2001

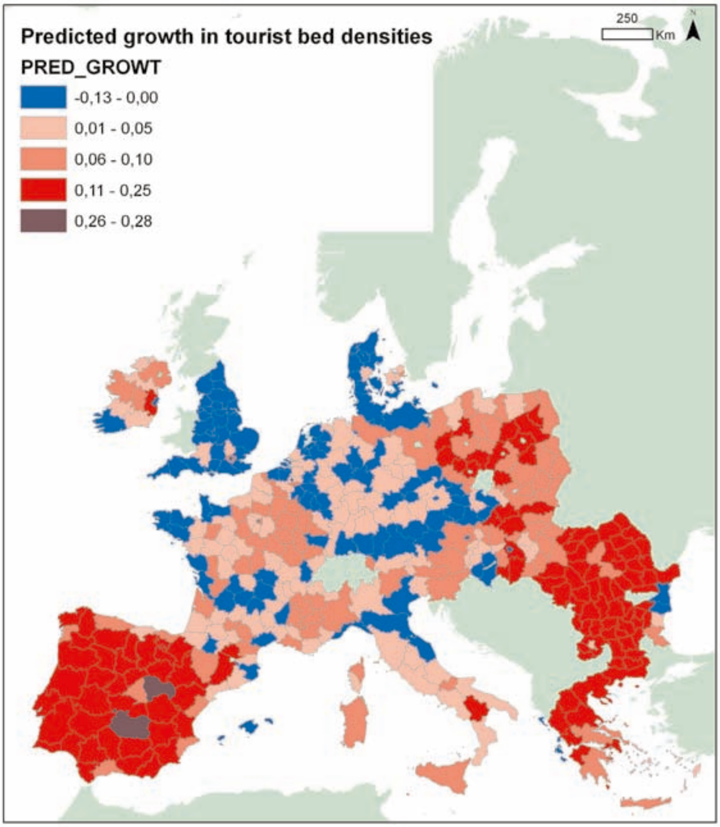

Fig. 6. predicted relative growth in tourist bed densities by NUTSX region, 1994-2001

Some of the predictors of tourist attractiveness -- such as climate and access to coast and mountains -- are likely to remain the same in the SENSOR scenarios for 2015 and 2025. Accessibility is likely to change in some parts of Europe, but this is not modelled within the SENSOR project, and the allocation of tourists in 2015 and 2025 must rely on the overall differences in accessibility within Europe in 2001. However, the remaining variables included in the regression models -- land use, population, GDP/capita -- will change the attractiveness of the single NUTSX region in response to outputs from the various models employed in the SENSOR project: CAPRI, EFISCEN, NEMESIS, the demographic model, and policy scenarios for nature protection. Furthermore, the 'saturation' tendency included in the analysis of tourism growth suggests a gradual redistribution of attractiveness for tourism in response to crowding at the destinations.

6.2 Land use/land cover effects

The analysis of tourist bed densities in 2001 as well as the analysis of growth has revealed significant effects made by the three land use factors: urban, nature and agriculture (see Table 3). The three factors have been derived from the Corine land cover data sets in combination with Corine biotope data and the European Environmental Agency map of urban morphological zones. Factor loadings by land use/land cover variable are shown in Table 7.

Table 7. Factor loadings of land use variables (measured in percent of land within region), by component/factor, resulting from principal component analysis and varimax rotation. Highest factor loadings are printed in bold.

Land use variable:	F1 Urban	F2 Agriculture	F3 Nature
Artificial surfaces	**0,981**	0,030	-0,023
Transport infrastructure	**0,880**	0,001	0,001
Agriculture	-0,403	**0,867**	-0,061
Forest and nature areas	-0,362	**-0,907**	-0,022
Wetlands	0,000	0,379	**0,660**
Corine biotope area	-0,026	-0,308	**0,741**
Urban Morphological Zone	**0,959**	-0,028	-0,016

The regression analysis has indicated that factor/component 1 (Urban) and 3 (Nature) are positively related to tourist attractiveness, while factor 2 (Agriculture) is negatively related to tourist attractiveness. To some extent, this may be the result of proxy effects, indicating an average level of associations between types of regions and tourist densities across Europe. Thus, employing the regression results to predict future geographical distributions of tourists implicitly involves assuming that these general associations between type of region and tourism will continue in the future. Given the geographical level, at which the modelling within SENSOR is undertaken, this is a reasonable assumption.

6.3 GDP and population

The analysis of tourist bed densities in 2001 indicates a positive effect of population density as well as GDP per. capita. The analysis of growth in tourist bed densities indicates a positive effect of growth in population density. These are likely to stem from a range of causal effects and mechanisms that is generally associated with wealth and population density.

Again using the regression result to allocate future tourism loads will imply the reasonable (best guess) assumption that these relations will carry on into the future. While most of the bio-physical attraction factors are relatively stable (climatic changes are not likely to take serious effect within the 2025 time horizon of the SENSOR project), some of the attraction factors are sensitive to the outcome of other SENSOR models such as the GDP and the population, as predicted through the SENSOR's demographic model and the NEMESIS model. Thus, the disaggregation of population and GDP forecasts to the NUTSX level can be incorporated in the evaluation of tourist attractiveness of NUTSX regions in 2015 and 2025 and will affect the distribution of tourists within the country.

7 Summary and conclusions

The multivariate regression models explained 79% of the variation in tourist bed densities by NUTSX regions in 2001 (Table 4), and 39% of the variation in relative growth rates between the regions (Table 6). The statistical explanation of the status-quo distribution of tourist densities clearly provides a better fit to the log-linear regression model than to the corresponding model explaining growth in tourist densities. The main explanation for the poorer result for the model explaining growth is probably the short time period covered and the many random movements on the tourist market that cannot be captured in rough and general models.

The modelling exercise presented in this chapter, however, produces consistently explicable results with respect to what factors and variables that are related to tourist loads in European regions. The predictors are summarised in Table 8, where they are also sorted according to their contribution to the statistical explanation (standardized regression coefficients, Beta).

Table 8. predictors of tourist bed densities in NUTSX regions in EU25+2, and growth in tourist bed densities in the late nineties. The variables are ordered by their contribution to the statistical explanation of tourist bed densities, with the most important variable in the top.

Tourist bed densities in 2001	**Growth in tourist bed densities in pct. p.a.**
GDP/capita (+)	Tourist bed density at the offset (-)
New member states (+)	Agricultural land cover (-)
Population density (+)	Temperature (warm and dry climate) (+)
Mediterranean coast (+)	Urban land cover / "Urbanness" (+)
Agricultural land cover (-)	Alpine areas (+)
Atlantic coast or English canal (+)	Precipitation (wet and temperate climate) (-)
Potential accessibility (multimodal, surface modes most important) (+)	Other coast than Mediterranean (+)
Nature land cover (Corine biotopes and wetlands) (+)	Potential accessibility (+)
Other coast than Atlantic/Mediterranean (+)	Growth in population density (+)
Alpine areas (+)	Nature land cover (+)
Urban land cover / "Urbanness" (+)	

At a more general level, the important variables are land cover and the mix of land uses in the region; climate; alpine areas; access to the coast; accessibility; population density; and the level of wealth.

The main differences between the statistical explanation of status quo and growth, respectively, are differences between 'old' and 'new' members of the European Union. The new member countries seem to have higher bed densities under 'ceteris paribus' conditions; and the importance of a saturation effect in explaining the growth in tourist bed densities (see section 8). Because of the lack of suitable time series on tourist beds from the new member countries, the data does not support conclusions on the importance of old vs. new member countries when it comes to tourism growth. Other sources, however, suggest that tourism growth is higher in the new member states (CEC & Eurostat 2006b).

Other differences between predictors of tourist densities and tourism growth, respectively, are the role of the climate. Climate factors have been omitted from the final model explaining bed densities in 2001. The insignificance of the climate within Europe is probably caused by the existing (historical) tourist industries in Northern Europe, which is counterbalanced by Mediterranean tourism. The growth trend is different, as relative growth significantly favours warm and dry climates at the expense of wet and temperate climates (northwestern Europe). This can be interpreted as a spatial redistribution of tourism within Europe that is probably driven by increasing levels of mobility and increased wealth. More complex climatic preferences by tourists were also found in a study across 15 European countries (Danmarks Turistråd 1999). Rather than a simple pattern of Northern Europeans seeking southern climate, sun-seeking and interest in different climates was found to be prevalent across most countries of both Northern and Southern Europe.

The high interest in coastal regions confirms the results of the Eurobarometer survey (European Commission 1998) where most European holiday makers choose the sea (63%) as their preferred type of holiday destination. Also, the interest in Alpine regions is supported, as 25% preferred the mountains as holiday destination. In contrast, the negative relation to agricultural areas is somewhat contrasted by the 23% of the respondents in the Eurobarometer survey who state their preference for the countryside as a holiday destination. However, this may be because the term ‘countryside’ encompasses much broader areas and experiences than do ‘agricultural areas’. The attraction of ‘urbanness’ is also supported by the 25% of the tourists in the Eurobarometer survey who prefer cities as holiday destination, but many of the tourist accommodation facilities also cater to business tourists, who tend to hold meetings in populated and easily accessible places such as cities.

Quite interestingly, the GDP is positively related to the number of tourist facilities. This is similar to results by Zhang & Jensen (2007), who find that within the OECD area, prices play a reverse role – higher prices attract more tourists. Zhang & Jensen explain this by these countries having been able to differentiate and augment the tourism product that they offer. The perception of the authors of this modelling chapter is also that the GDP per capita variable more likely reflects a thriving local economy that facilitates the development and expansion of tourist services as part of a diverse economy and hereby becomes a hot-spot for travellers, rather than the higher GDP being a result of many tourists.

Overall, the attraction modelling has identified a number of key attraction factors in the destinations which to a large extent explain the great variations in the location of tourist overnight facilities. This direct modelling of the supply-side attraction factors has not been identified – as far as we have been able to find – in any other studies at this scale and level of detail (NUTSX level). Focus in tourism modelling is clearly on the demand side and on understanding what stimulates or limit peoples travels rather than what they seek to find in the destinations. While Zhang & Jensen (2006, in print) attempt a supply-side modelling approach, this is still based mostly on economic and development factors, while natural, cultural and, climatic factors are included only as a country-specific dummy. This study finds this country-specific dummy to be highly important but does not include any specification or data about it. In contrast, our modelling produces results with direct identification of key attraction factors, using these to establish an attraction index to be used in allocating tourist flows at the sub-national level.

8 Future refinement of the modelling

The results of the models in this chapter can be interpreted only by reference to the list of variables available for analysis in the first place (see appendix in Kaae et al. (2007). Due to limited data, potentially important attractors of tourists have been omitted, e.g. cultural facilities, expenditure on culture, 'events', and environmental quality. Some of these variables are not available at the NUTSX level, and it is necessary to satisfy with proxy variables such as wealth and population density (as included in the models). Aspects of environmental quality can probably be described based on available environmental data; however, changes over time will be more difficult to represent. The analysis of growth in tourist bed densities could be improved, and the report is reinforced in its conclusions through the inclusion of additional changes in explanatory variables over time, e.g. land use patterns and accessibility. Completion of the analysis with this type of data will be attempted in future revisions within the SENSOR project.

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Landscape level simulation of land use change

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Abstract

Land use changes are a result of decision making at the local level which is influenced by changes in the regional and global economy, demography, policies and other factors operating over a wide range of organisational levels and spatial scales. This chapter describes a methodology to integrate the demands for changes in land use as determined by global and national scale processes with local level conditions influencing land use conversions across the European Union. The approach enables an assessment of landscape level changes in land use and the analysis of policies specifically aimed at land use and landscape functioning. A baseline scenario is presented to illustrate the approach and results.

Keywords

Land use, Europe, spatial analysis, simulation, landscape change

1 Introduction

Changes in demography, demand for agricultural products and space for housing and industry, global trade and economic development are important factors that potentially lead to large changes in landscapes, not only through the conversion of land use, but as well through the modification of the farming intensity and structure. These changes can be stimulated or counteracted by policies aimed at the agricultural sector, nature protection

or directly aimed at spatial planning of land use, for example the planning of compact urbanization. The likely impacts of these developments and policies on environment, landscapes and rural livelihoods are largely unknown. As policy makers need to act in an anticipative or pro-active manner they need to be informed timely on what will or could happen and on what may be done to lessen risks and to stimulate promising developments. Different types of research that potentially support policy makers in the identified challenges are available (Bennett et al., 2003). Research may aim at designing solutions for specific problems by calculating the optimal land use allocation given a set of objectives (Loonen et al., 2006; Matthews et al., 2006; Seppelt and Voinov, 2002; van Ittersum et al., 2004). Such studies may be used to determine optimal locations for urban development or intensive agriculture to minimize negative impacts on other land use functions. Other studies aim at the evaluation of the consequences of specific policies on land use (Britz et al., 2002; Meijl and Tongeren, 2002; Rounsevell et al., 2006a; Verburg et al., 2006a). The latter type of research aims at the evaluation of policy decisions and can therefore provoke policy discussions on the intended and un-intended effects of such policies and their alternatives. The SENSOR project, described in this book, aims at this type of policy support on land use change.

Because it is likely that the policy impact depends on change in demography, economy and other factors as well, it is needed to test the effects of the policies under different scenarios. Such scenarios are a means to capture some of the uncertainty in development of the main driving factors of the land use system. Scenarios have therefore become an important tool in policy support studies (Peterson et al., 2003; Rotmans et al., 2000; Wester-Herber, 2004; Xiang and Clarke, 2003). In the SENSOR project three scenarios are used that differ in assumed growth rates of economy and demography (Kuhlman, 2008).

Many scenarios studies, including a quantitative assessment for policy support, have been conducted in recent years (Busch, 2006), e.g. the climate change related studies of the Intergovernmental Panel on Climate Change (Arnell et al., 2004; IPCC, 2000), the Global Environmental Outlook (UNEP, 2002) and the Millennium Ecosystem Assessment (MEA, 2005). However, in most of these studies the spatial resolution of analysis is limited to 50x50 kilometre due to the dependence on global scale models (Strengers et al., 2004). Also the European assessment by the Advanced Terrestrial Ecosystem Analysis and Modelling project (Rounsevell et al., 2005; Schröter et al., 2005) and the PRELUDE project (EEA, 2005) does not go below a spatial resolution of 10 minutes. Such a coarse resolution is not sufficient to identify changes in landscape pattern given the importance of local conditions for landscape changes. Although macroeconomic demands and demographic pressure are important drivers of land use change at the national scale, most decisions concerning land use conversions are made by individual land owners and managers that also respond to the local environmental and socio-economic context. The large diversity in environment across Europe makes it important to account for the different conditions these actors are facing. A high spatial resolution enables to account for the typical multi-scale influence of the driving factors that steer the competition of the different land use sectors for land resources. Different landscapes are expected to react differently to these internal and external pressures. Current studies at the European extent do not provide sufficient detail to assess the landscape level impacts. There is no agreement on the most appropriate scale in terms of resolution and extent for studying landscape change (Gardner, 1998; Wu and Qi, 2000). Ideally multi-scale approaches would be conducted. This paper will present a method that uses a much more detailed spatial resolution than previous studies at the European extent and will enable to identify a number of critical changes in landscape structure and composition. Also for sustainability impact assessment of land use effects on issues like biodiversity and carbon stock changes a high spatial resolution is needed since most impacts are dependent on the characteristics of the location. An additional argument for a spatial approach in the analysis of land use change is related to the policies that need to be evaluated using the modelling framework. Many policies aimed at rural areas are focusing on specific areas that do not always correspond to national or administrative areas. Examples of such policies include the Less Favoured Areas Compensation scheme targeted at rural landscapes and livelihoods and the Natura2000 network which is targeted at biodiversity conservation.

This chapter describes the approach for simulating land use changes as used in the SENSOR project. The methodological discussion is illustrated with an example for one scenario to show how the results can be used to support policy discussion.

2 Methodology

2.1 Overall approach

Land use change is the result of human-environment interactions at different scales: from trade of commodities at the global level to the effect of soil conditions on land management of a specific farm field. Within SENSOR land use change is analysed by several research groups that each focus on a particular set of processes, scale and sector. In addition to these sectoral analyses, multi-sectoral models are used that deal with the competition and interactions between these processes over different scales and the different economic sectors directly related to land use. Such multi-sectoral analysis is needed because different sectors often compete for the same land resources. It is often the interaction between the changes in the different land use sectors that determine the change in landscape and the potential multi-functionality of the land use system. When such a multi-sectoral analysis would be conducted at the national level only it would still be hard to identify whether or not sectoral changes result in a further integration or segregation of land use functions: multi-functionality is determined by the interaction of the different sectors over a range of different scales from the regional demand to local potentials.

The major economic processes leading to land use change at the scale of individual countries are captured by the NEMESIS model (Brecard et al. 2006), while a more detailed allocation (disaggregation) of land use change within the countries is done by the Dyna-CLUE simulation model. Figure 1 illustrates the approach that is followed. Besides the multi-sectoral analysis of both NEMESIS and Dyna-CLUE a range of sectoral analyses and models are used. Partly, these sectoral models are integrated in the NEMESIS model to determine the land requirements by the different sectors. In other cases the sectoral models are used to derive simplified relations between drivers and changes within the sector that can be used within the multi-sectoral models. The model coupling is described in more detail by Jansson et al. (2008).

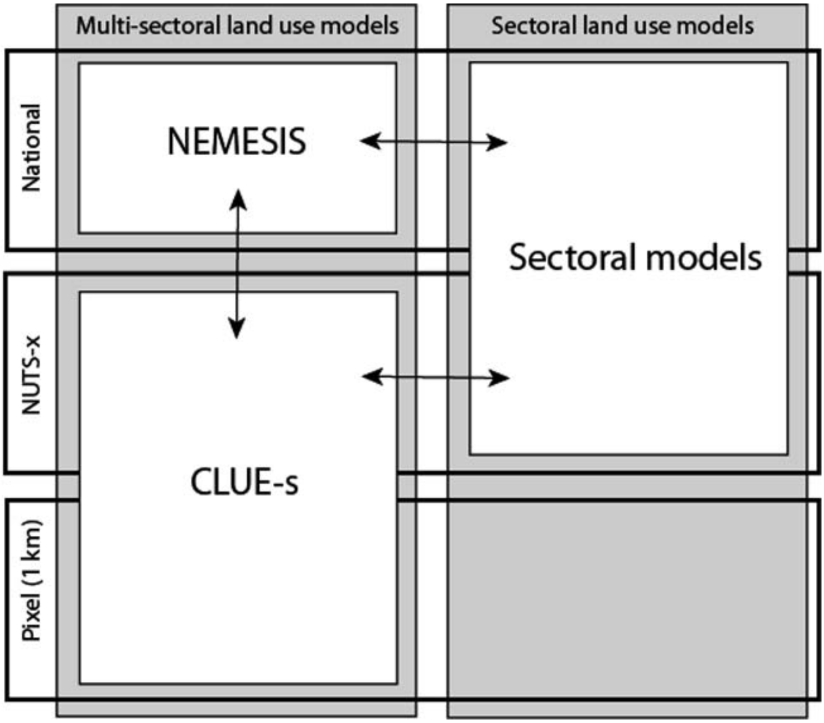

Fig. 1. Overview of modelling approach at different spatial scales

2.2 Dyna-CLUE modelling

The Dyna-CLUE (Conversion of Land Use and its Effects) model is a tool to simulate the spatial allocation of land use changes (Verburg et al. 2002, Verburg et al., 2006b). The model combines a number of popular, well-established approaches that have evolved in land use modelling over the past decades (Verburg et al., 2004b). In this sense the model may be classified as a spatial dynamic, hybrid land use change model that is based on pixel-level simulation. The choice of using pixels, spatial entities, instead of agents as basic units of simulation is based on the difficulty to parameterise agent-based models beyond the local level where appropriate data may be collected by interviews. For regional to continental scale applications the use of agent-based models is therefore considered difficult and mostly inappropriate (Matthews et al. 2007).

Depending on the study area and scenario conditions the user can configure the Dyna-CLUE model in different ways to address specific scenarios or policy cases.

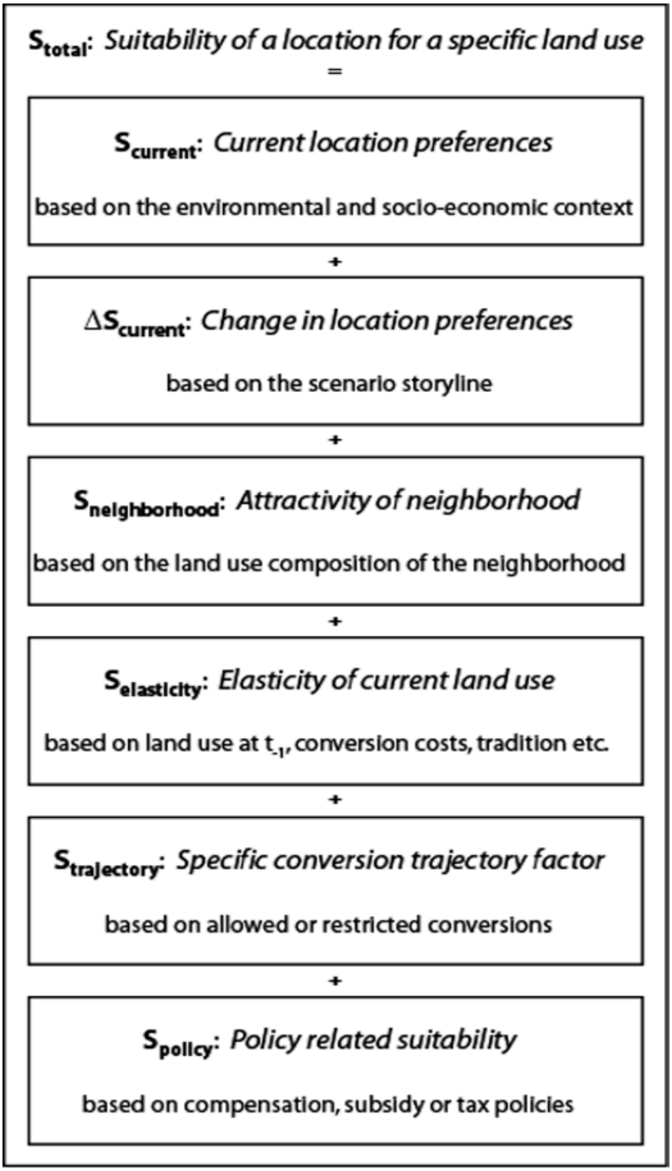

Fig. 2. Components used to calculate the suitability of a location for a specific land use

The model is based on the dynamic simulation of competition and interactions between land use types. The actual allocation is based on a set of constraints and preferences that reflect the characteristics of the land use type, location and the assumed processes and constraints relevant to the scenario. Given the competitive advantage of a specific land use type as determined at the national level by the economic models, each location is used for the land use type with the highest suitability at that location. The suitability is calculated as the sum of a number of values that reflect the determinants of the total suitability (Figure 2). The main determinant of the total suitability is the current location preference in response to the location characteristics such as soil, slope, climate and accessibility of markets. These preferences can be estimated based on expert knowledge or by econometric models (Verburg et al., 2004a).

While econometric models can only be based on current or historic conditions it is possible to update this location suitability by scenario specific decision rules that reflect changes in land allocation decisions, e.g. reflecting a more rational land allocation. Especially for urban land uses the neighbouring land uses may be an important determinant of the location suitability.

Agglomeration effects and economies of scale can lead to a preference for urbanization in the neighbourhood of current urban areas. This factor needs to be updated during each time step to reflect changes in neighbourhood composition during the simulations. Another component of the total suitability may be based on the current land use pattern and reflect the relative elasticity of land use changes. Most land conversions involve high costs and land owners are often reluctant to change land use as result of tradition or tenure conditions. Depending on the land use type considered it is possible to increase the suitability for a certain land use type if that location is already occupied by that specific land use type.

The ‘specific conversion trajectory factor’ reflects modifications in suitability as result of physical conditions or policy regulations, e.g., it is very unlikely that current urban areas are converted to agriculture. Therefore, the suitability of urban area for agricultural use is drastically decreased by this factor. On the contrary, policy may subsidize certain conversions at specific locations. It is possible to include this type of policies by increasing the suitability at that location for the targeted land use type. The total suitability of a location for a specific land use type is the weighted sum of these different factors. Differences between scenarios are obtained by differences in demand and the values that make up the total suitability of the different locations.

The approach considers 17 different land use types which include: rainfed arable agriculture, irrigated agriculture, arable land devoted to the cultivation of biofuel crops, grassland, abandoned agricultural land, built-up area, forest, semi-natural vegetation, and a number of land use types that are assumed to show little dynamics in time (including beaches, glaciers and bare rock). Land that is identified by the model as abandoned farmland can develop spontaneously into semi-natural area and, ultimately, into forest. The time needed for spontaneous regeneration of natural vegetation is location dependent and based on the growing conditions, grazing pressure and human intervention.

3 Results

Figure 3 to 6 show, aggregated at the level of NUTSx regions (a combination of NUTS2 and NUTS3 regions of comparable size) the resulting changes for the most important land use types in the Baseline scenario (Kuhlman, 2008) of SENSOR. The differences in land use change between the different member states are a direct result of the simulations performed with the NEMESIS model (Brecard et al., 2006). It should be noted that the NEMESIS results are currently based on a preliminary model run while improvements of the model are underway. Overall quantities of change are a reflection of the macro-scale results of the NEMESIS model.

In contradiction to other scenario studies of future land use in Europe including EURURALIS (Meijl et al., 2006; Verburg et al., 2006b), ATEAM (Rounsevell et al., 2006b) and SCENAR2020 (Nowicki et al., 2007) the sensor baseline scenario predicts increases in agricultural area in several European countries, especially for arable agriculture. These increases result from continued market support together with a growing worldwide demand for agricultural products. In combination with a continuing urban growth this leads for a number of countries to a loss of semi-natural vegetation and forest. From the results it is clear that large differences between the different NUTS regions within the member states exist. Due to differences in environmental and socio-economic conditions different regions will respond differently to the national level changes in demands for land. It is clear that agricultural abandonment will, in most countries, take place in those regions that have the least favourable conditions for agricultural production although this is counteracted to some extent by the less favoured areas compensation scheme of the European Unions that compensates farmers in designated regions for the less favourable production conditions. Other regions with decreasing agricultural area coincide with regions that face high urbanization. Urban land demand often out-competes agricultural land, even in areas that are relatively suitable for agricultural use. Most expansion of agricultural area takes place in regions that have favourable conditions for agriculture with, in the current situation, unprotected areas of natural vegetation.

These different trends together with strong differences between countries lead to a very diverse pattern of agricultural land use change across Europe. The pattern of urbanization is mostly based on current concentrations of urban areas. The changes in natural vegetation are reflecting the consequences of both agricultural change and urbanization. Natural areas protected by the Natura2000 networks of protected areas are unchanged or see an increase in natural vegetation as result of land abandonment. Regions with large increases in either urban or agricultural area inevitably will face more pressure on natural areas.

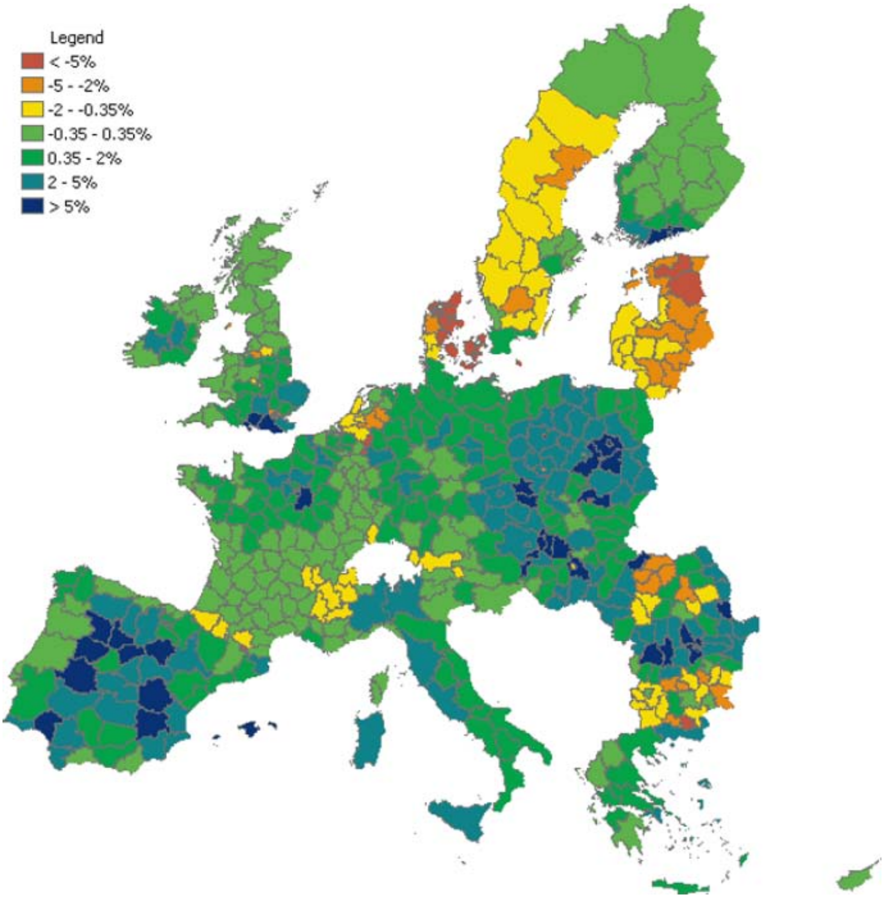

Fig. 3 Change in agricultural area between 2000 and 2025 (relative to the total NUTS area)

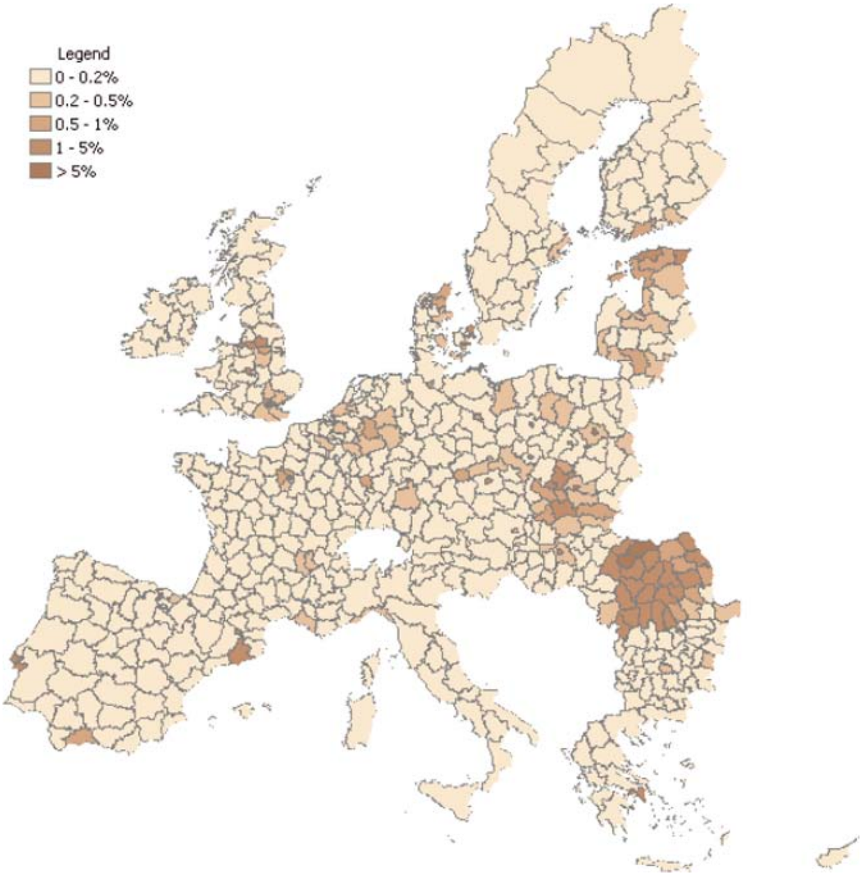

Fig. 4. Change in built-up area between 2000-2025 (relative to the total NUTS area)

The results presented in Figure 3 to 5 are aggregated at the NUTSx level to provide an overview of the most important land use conversions across Europe. However, these results give little insight in the changes in landscape within these NUTSx regions. Even within NUTSx regions land use change often has a high level of spatial variation leading to differential impacts.

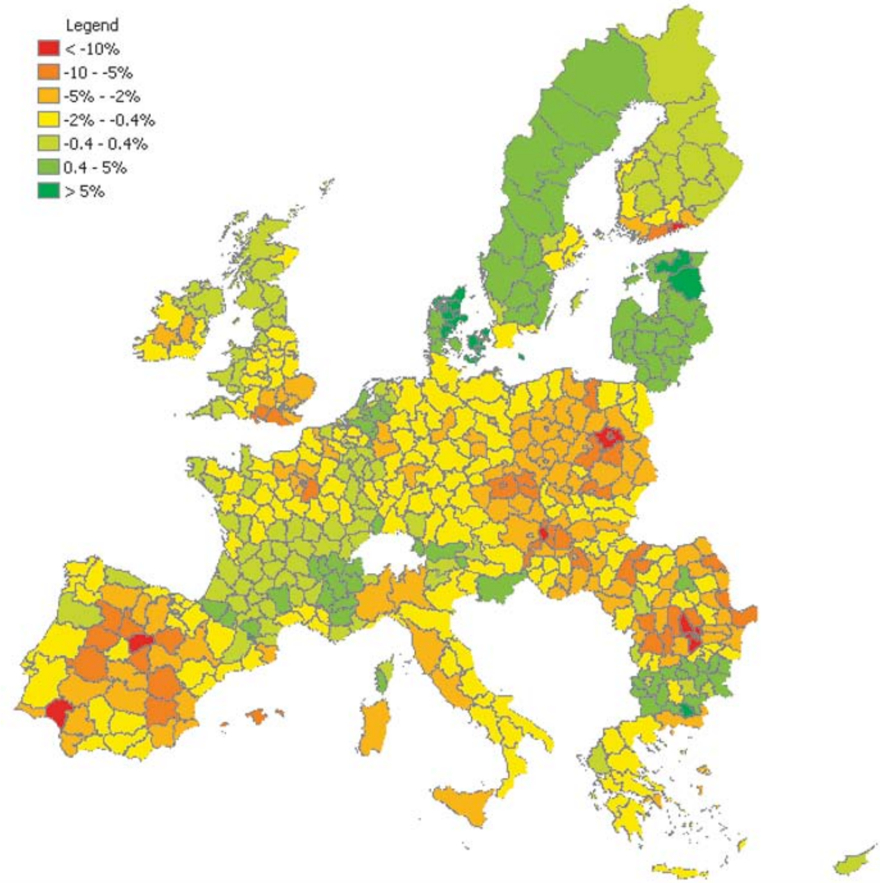

Fig. 5. Change in natural areas (relative to the total NUTS area)

The results at a spatial resolution of 1 km^2 do allow an analysis of landscape changes for specific regions showing the different trajectories of land use change. Based on these changes in landscape it is also possible to assess the possible consequences of these changes on biodiversity, carbon sequestration, soil erosion and other, landscape related, indicators.

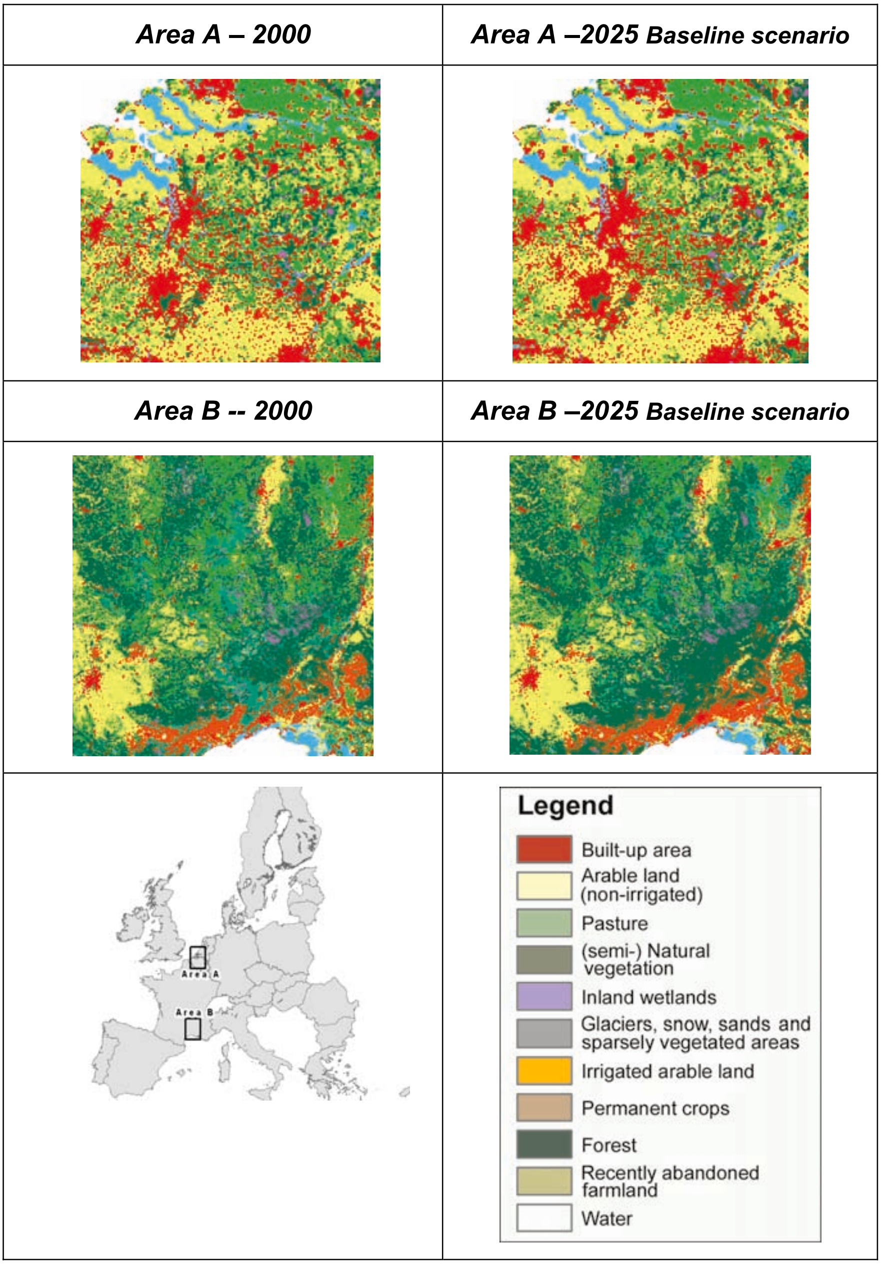

Fig. 6. Two examples of regional impacts of land use change

Figure 6 gives examples of these landscape level changes for two areas with diverging developments. Area A represents the urbanizing region of the southern Netherlands and Belgium. Apart from a continuing urbanization with large spatial impacts agriculture also remains an important land use during the period of simulation. This comes at the cost of a large number of small patches of forest and semi-natural vegetation. The protected forest areas are however well-preserved. A contrasting development is found in southern France. Large parts of this area are marginal for agricultural use and demographic projections indicate a further depopulation of the area. Agricultural areas will therefore be abandoned and gradually convert into semi-natural vegetation and forest. The southern part of the area is dominated by permanent crops, mostly vineyards. These are expected to expand during the simulation period.

4 Discussion

The integrated, multi-sectoral, approach presented in this chapter is essential when analysing possible policy effects on the (multi-)functionality of landscapes. Although the regional or national aggregate change may be an important measure of the consequences of certain developments, it does not provide insight in the impact of the changes for the landscape itself. The functionality of a landscape is typically a result of the regional context and local potentials. This study has indicated that changes in land use are not evenly spread over a country or region but show distinct spatial patterns. Although the aggregate decrease in agriculture for a country may be very modest, some regions within the country may still face a considerable decrease of agricultural area with large impacts on landscape, livelihood and environment.

These locations may face large changes in current functionality, but may as well provide potential for the development of alternative or new functions. The visualisation of land use change patterns is also helpful in discussing the options of alternative policies or design targeted measures aimed at critical regions or processes of change. At the same time the analysis at the European extent helps to frame local case studies (Eetvelde and Antrop, 2004; MacDonald et al., 2000) in a wider context and may help to indicate for which areas similar developments can be expected. Visualisation of the main conversions in maps may be supplemented by other visualisation techniques to support the discussions on future land use and landscape change (Appleton et al., 2002; Dockerty et al., 2006).

In this chapter we have only presented the results of a baseline scenario of changes in Europe. It is, however, not difficult to imagine that also for other scenarios or for specific policies similar simulations can be conducted comparable to previous scenario studies (Busch, 2006, Verburg et al., 2006a). In case of other scenarios it is most likely that the demands for urban and agricultural area are different at the national level, which may affect areas not affected in the scenario presented in this chapter. For the evaluation of specific policies it is possible to regionally adapt the constraints and options of the land use allocation procedure: e.g., nature protection policies may be implemented by excluding the protected areas from potential conversions. This way it is possible to evaluate both the European-wide pattern of land use change as well as the specific trajectories of landscape change within the different European regions. This type of information can be useful to assess impacts on land use change while, at the same time, it visualises the potential changes in landscape for use in policy discussions. The high level of integration between sectors and between economic and environmental drivers of land use change may be an incentive for a balanced evaluation of land use related policies that determine the future of the (multi-) functionality of European landscapes. At the same time it should be noted that, in spite of the high spatial resolution, it is not possible to use the results for the analysis and planning of individual regions and landscapes. Although general trajectories of land use and landscape change can be identified more detailed, region specific studies are needed that include region specific data, location factors and policies. Rather, the analysis at the European level can assist in pin-pointing regions of prime interest for such more detailed explorations or help to identify regions with similar land use trajectories and impacts.

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Part III

Spatial representation and data issues for European regions

Regional socio-economic profiles for assessment of European land use related policies: the SENSOR experience

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Abstract

Appropriate statistical profiles reveal differences in socio-economic contexts that need to be taken into account when assessing European policies. Since the SENSOR project aims at assessing the effects of regional differences in European developmental trends, and of policy scenarios on issues related to land use multifunctionality and linked sustainability, representative sets of European Regional Economic Profiles (REPs) were required. Furthermore, using landscape structure analysis, these profiles were integrated, together with land use management and biophysical parameters, into a Spatial Regional Reference Framework (SRRF) which revealed the main contrasts between European regions.

Socio-economic indicators, coming mainly from EUROSTAT, generally underline differences in economic development modes and in social conditions in Europe, at country or at regional level. In establishing REPs it was crucial to select indicators which could fulfil three general requirements: firstly, their presence in all European regions; secondly, their capacity for creating a significant set of regional profiles within the whole of Europe; and thirdly, their ability to reveal differences that can be interpreted in terms of pertinent issues. SENSOR benefited greatly from the experience of ESPON (European Spatial Planning Observation Network), but had to design a method for selecting a limited set of indicators which satisfied the last requirement. The main focus was placed on indicators which revealed human pressures on the land use functions under consideration in

SENSOR - assuming that those socio-economic functions assigned to land uses are sensitive to the intensity of these pressures, which moreover may also affect environmental functions.

Finally, SENSOR REPs are composed of a few core socio-economic indicators introduced in the SRRF, which reveal the most relevant regional differences in economic potential, in human presence and in spatial settlement structures, supplemented by some sectorial indicators. They cannot reveal the whole complexity of socio-economic assets in European regions, however, they proved to be efficient in showing the variety of socio-economic conditions within sets of regions which have similar landscape structures and which would thus be, to a lesser or greater degree, sensitive to changes which were further assessed in SENSOR.

Keywords

Socio-economic indicators, regional economic profiles, pressure indicators, economic assets, spatial settlement

1 Aims and problems of Regional Economic Profiles

Regional Economic Profiles (REPs) are usually short informative documents which show key data and indicators. They deliver objective and concise information on the current socio-economic state of a region, and on the main changes taking place in conjunction with development trends. The key aim of REPs is to provide basic information, but they can be developed into comprehensive diagnoses of socio-economic status quo by further analysis of the main changes and issues confronting regions (IAURIF, 2002; SWEDA, 2006). However, since each region has its own characteristics, there is no single model for REPs. It is possible to focus on certain aspects of particular local relevance; for instance, agricultural decline, sustainability of tourism, population ageing or migrating, and social heterogeneity. Moreover, their content may differ from one region to another, due to differences in the availability of data.

Thus, starting from key economic and social data which carry a clear and easily understood message, REPs first of all describe the main characteristics and changes that will help in the identification and better understanding of developmental issues. Since regions are faced with a variety of these, when establishing REPs, the challenge is to keep a subtle balance between the provision of basic information on general trends and making provision for further analyses of the most important issues. In this respect, a decision must be made about which socio-economic characteristics deserve particular attention. Lastly, when it comes to establishing REPs for the whole of Europe, it is valuable to reveal salient regional differences that are meaningful in a pan-European perspective. This needs to be based on comparable data and indicators for all European regions, and to be able to cope with differences between most needed and best available data.

Research projects which focus on land use or environmental issues commonly investigate differences resulting from the socio-economic context, and there is thus a call for the establishment of REPs, which can provide further information on socio-economic characteristics and advance the analysis. This is especially relevant for the SENSOR project, which aims to assess regional impacts of European policy scenarios on multifunctional land use. That is why SENSOR called for REPs which could reveal the main ways that the relevant socio-economic parameters differed between European regions. In SENSOR, these REPs were designed to be integrated, together with bio-physical aspects, through landscape structure analysis into the SENSOR Spatial Regional Reference Framework (SRRF), presented in Chapter 16. The SRRF groups homogeneous sets of NUTSx regions (Nomenclature of Territorial Units for Statistics - NUTS2 or NUTS3 regions, depending on countries) into 27 ‘cluster regions’ that would be relevant through the course of the project. The chief differences underlined in the REPs, and further in the SRRF, are those considered prominent in the final assessment of the regional impacts of the main European developmental trends, and of policy scenarios on the Land Use Functions (Pérez-Soba et al., 2008).

In this respect, when establishing REPs, SENSOR had to deal with the issues discussed above, as well as addressing the questions of data availability and comparability, and their relevance for selected socio-indicators, with the view of assessing multifunctional land use sustainability. Where possible, SENSOR used previous pan-European experience to select relevant indicators, but these needed to be adapted to address those land use sustainability issues which are fundamental to SENSOR. Therefore the REPs had to focus more on socio-economic characteristics which would help in analysing land use sustainability concerns. It resulted in identifying sets of indicators that could be integrated in the REPs, but it was important to rank them according to their capacity to meet, as far as possible, three main requirements commonly assigned to REPs: firstly, availability in all European regions; secondly, a capacity to draw a significant set of regional profiles within the whole of Europe; and thirdly, the ability to reveal differences that would clarify issues that needed addressing.

In fact, because of problems of availability and comparability, only a few indicators proved to be currently usable in all European regions.

Among them, the selection included those economic and social indicators which show important contrasts between regions, and simultaneously best characterise socio-economic changes and policy drivers which have effects on land uses. In addition, care was taken to identify a very limited set of core indicators to be introduced in the SRRF, which were supplemented with other indicators, referred to in the six SENSOR sectors, for which land is a basic resource (e.g., agriculture, forestry and energy). However, the selection process emphasises the conflict between the need for a comprehensive set of indicators to reveal the variety of socio-economic assets in European regions and their limited availability. SENSOR did not manage to avoid this difficulty, which is inherent in all similar exercises. Discussion between SENSOR experts helped to find operational solutions, which guided the final choice of indicators.

2 Existing sources for REPs: regional typologies and availability of pan-European data

SENSOR REPs were established at an early stage of the project, when guidelines for selecting indicators that would help in assessing land use sustainability were not fully formulated Frederiksen and Kristensen (2008). First of all inspiration was sought from previous pan-European experience that had successfully revealed differences in regional socio-economic contexts; and the variety of development issues which face European regions; and in analysing the constraints of data availability which confront REPs.

Current developments in regional typologies

A literature review was undertaken regarding regional socio-economic typologies set up at country or European levels, since these typologies aim to reveal salient differences between regions and, in addition, are based on sets of available indicators. It showed that most of them were established with the objective of guiding regional development policies, and thus the prime aim was to reveal regional imbalances that needed to be overcome. Recent developments in typological work resulted from changes in the issues which focused on in these policies. However, most references concern typologies established at a country level, which highlight differences within a country. Typologies at an international scale, which reveal regional differences within the whole of Europe, are scarcer. The reasons for this include the basic necessity, when a country attempts to reduce regional socio-economic imbalances, of recognising the main differences in development within the country that must be taken account when formulating policies - even when they are supported by EU funds. Pan-European typologies would not necessarily reveal contrasts which are specific to a country, since they concentrate on salient differences between regions with European policies being the primary focus. The main results of the review of recent typological works concerning Europe's regions follow.

Regional cohesion is always the main European policy objective, which led to the establishment of various typologies. For example, they address regional differences in economic development (Charleux, 2001) or new spatial patterns which emerge in Europe (Vandermotten and Marissal, 2000). However, typological works have focused in recent years on issues which call for more specific information to guide European regional development policies; notably, as a result of the Lisbon objectives. For example, the EU has funded a study which resulted in a regional typology focused on technological development issues (Clarysse and Muldur, 2000). It brought to the fore differences between European regions based on their current state of economic and technological development, their short-term evolution in technological development and their short-term economic growth. With respect to another current issue, namely competitiveness, the Dutch ECORYS Company (http://www.ecorys.com) has developed toolkits to measure the competitiveness of a region or of a city, by examining in depth a range of factors of regional competitiveness and classifying European regions according to five themes (innovation, entrepreneurship, economic governance, globalisation, and quality of place): these factors could provide the framework for a regional typology.

However, even when the main focus has been on issues connected with the Lisbon objectives, common issues related to EU policies have not been ignored, since the European Spatial Development Perspective (ESDP) (CEC, 1999) gave a new imperative to typological works. The ESDP encouraged the revision of European policies by concentrating in greater depth on the spatial effects of European policies, and thus focused on aspects which had not previously been tackled at European level, such as urban development or rural-urban relationships. Typological works were developed in the ESPON programme, which aimed at revealing the variety of spatial development patterns in Europe. The first ESPON projects, completed in 2003-2005, resulted in various pan-European typologies of NUTS2 or NUTS3 regions. They variously took into account thematic fields of spatial development, including the environment, accessibility and the spatial structure. For example, the ESPON project 1.1.2 'Urban-rural Relations' (ESPON, 2004b) established a typology identifying differences in the character of regions on a successive gradation from urban to rural.

Based on the idea of two main analytic dimensions, namely the degree of urban influence versus the extent of human intervention, this typology defines different types of regions through four indicators: the population density; the share of agricultural areas and of artificial surfaces; and finally, the status of the leading urban centre of each region.

In addition to regional typologies established for the whole of Europe, typologies concerning specific areas have occasionally been developed. For example, the Nordregio team established typologies of mountain regions, aiming to appreciate differences in their development in respect of orientation towards European mountain policy (NORDREGIO, 2004). They focus on spatial patterns of population development, accessibility of transport and services, and of land use and cover in mountain regions. They demonstrate where these spatial patterns are specifically related to mountain conditions, or concentrate on core-periphery schemes, such as traditional contrasts between the European pentagon and surroundings and more distant areas, irrespective of mountain conditions.

Finally, the review revealed that the main differences between typologies referring to economic and social development arise from contrasting issues, or even policy objectives, specifically addressed through the projects concerned. Regions are characterised with respect to pre-defined considerations which guide the indicator selection; e.g., potential for knowledge based economic activities, or ability to provide access to employment. However, no example of a European typology which specifically refers to concerns of land use sustainability has been found, although these issues could be involved to a greater or lesser degree with those addressed in ESPON. Through combining economic, social and environmental indicators, they aim at characterising spatial development in Europe and therefore may address multifunctional land use. This led to further reflection on the ways in which the main socio-economic and policy drivers result in regional differences that address, not only common development issues, but also land use sustainability and multifunctionality. The conceptual framework of SENSOR REPs, presented in the following section, was designed to make it possible to consider multifunctional land use on an initial basis of common social and economic indicators.

Pan European data availability

In common with all typologies mentioned above, the establishment of REPs needs to be based on comparable data and indicators which are currently available at the regional level. In addition, the question of the relevant geographical scale of analysis needs to be resolved, in respect of the issues addressed, since contrasts between NUTS regions mask disparities that would be important at a more local level. With this in mind, SENSOR decided to focus on the NUTSx regions, omitting issues that call for more detailed spatial analyses, and comparable data available in all NUTSx regions were sought.

Ready to use data referring to NUTSx regions come initially from the regional database from Eurostat, which is called REGIO (EUROSTAT, 2007). Eurostat is a general directorate of the EU commission that is in charge of gathering comparable statistical pan-European data, especially at regional level, which are provided by respective countries and need to fulfil quality criteria. They refer to various domains, e.g., agriculture, economic accounts, transport, science and technology. However, the list of required domains follows the European political objectives which called for comparable data, such as those referring to the CAP or to EU regional policy. This is why data about agricultural holdings or disparities in terms of employment are relatively widespread, in comparison with data addressing issues which are more peripheral to the concerns of the EU; for example, housing provision or living conditions. Eurostat databases also keep track of recent enlargements of the EU: there are still differences in data availability between long standing and more recent member states. In addition, Norway and Switzerland are not, in theory, within the scope of Eurostat activities: data need therefore to be sought in applicable countries. Other current shortcomings in Eurostat databases arise, for example, from differences in time periods of the data provided by the member states, or gaps in series. Thus some data are missing because they have not yet been established in a country, or because they do not comply with Eurostat quality standards. Nevertheless, one main advantage comes from the fact that Eurostat provides free on-line access to all databases and to related meta-data.

Apart from Eurostat, the most active institution dealing with data availability and comparability issues, and with relevant indicators at regional level, is the OECD (Organisation for Economic Cooperation and Development). Its Territorial Policy Development Committee made efforts to check the availability and the comparability of regional data that could help to guide regional policies for managing changes in developmental trends and related issues (OECD, 2002a to 2004c). The OECD proposed some indicators which, in comparison with Eurostat indicators, go further in analysing development issues, but access to OECD databases is less straightforward. However, the list of indicators which are actually available and comparable for all European regions is rather limited, in contrast to the richness of regional data and indicators produced *within* European countries, although these have the disadvantage of not being strictly comparable from one country to another.

Many European projects have been faced with these constraints of data availability and comparability, but only few of them have focused on finding efficient solutions to overcome these problems.

The most important advances were made in the course of ESPON projects. In particular, project 3.1 'Integrated tools for European spatial development' (ESPON, 2005) accumulated a great deal of experience in filling gaps in data availability, which had hampered spatial analyses performed in other ESPON projects. It succeeded in completing a pan-European regional database, utilising NUTS2/3 regions[1], involving the 27 current EU member states, plus Switzerland and Norway. Data derived from Eurostat REGIO database or other European or national databases were complemented where necessary to make regional comparisons possible.

This database, which is unique in Europe, integrates ESPON results, as well as fundamental regional background information, to analyse European regional structure and trends, including statistical data and indicators or typologies that provide the common bases of ESPON projects. Common and genuine indicators, referring to specific issues investigated in ESPON, are stored in this database. For example, ESPON established accessibility indicators which are derived from statistical data using GIS procedures. Unfortunately, project 3.1 ended in 2005, so that most data refer to 1999 or 2000. Since the end of the project, only a few data have been updated. However, in the meantime on line access has now been provided to ESPON main indicators and to mapping facilities.

For the above reasons, few socio-economic indicators are currently available for all NUTSx regions, notably those which are currently mapped in the Eurostat annual Regions Statistical Yearbooks (EUROSTAT 2006-2007); e.g., GDP per inhabitant, unemployment rate, share of agriculture in the GDP and the active population. However, the ESPON database provides other indicators which, even when not updated, may be used in REPs, since they reveal the most permanent spatial characteristics and can therefore be related to the usage of land.

[1] This is according to the definition of the NUTS regions in force at the period to which the data refer (or their equivalents in non-EU countries). In fact, in the ESPON 3.1 project, NUTS regions were those in force in 2000, namely the 'NUTS99'. Some changes occurred in NUTS regions in 2003 ('NUTS03'), with regard to Germany, Italy, Spain, Portugal and Finland. At present the REGIO database refers to the NUTS03.

3 REP conceptual framework for SENSOR

Conceptual approach

The first stage in REPs is to decide what should be included, with regard to multifunctional land use sustainability issues, which are central in SENSOR. A conceptual approach was therefore necessary to make it possible to address these, both in the REPs and in the regional assessments. SENSOR adopted a functional approach to integrate social, economic and environmental impacts of land use change, utilising REPs based on the assumption that socio-economic conditions exert influences on functions assigned to land uses. These functions may be economic, social or environmental; for example, cultural functions are part of the social sphere and refer notably to the benefits people obtain from the landscape or amenities. The regions are composed of various units, where combined land uses result in coexistence and complementarities between different functions. Multifunctionality therefore means maintaining functional diversity, without major imbalances.

Using this approach, SENSOR REPs have been designed to focus on socio-economic characteristics and changes which underpin the level of performance of the various functions assigned to the land uses. Socio-economic indicators reveal developmental trends which have effects on human activities and on their contribution to various functions, whether productive, residential, cultural or leisure related, and often leads to important functional changes, such as a decline in biodiversity. However, it may be difficult to manage impacts of changes in human activities on social and economic functions in the cause of reducing impacts on environmental parameters.

Indicators like GDP, or the unemployment rate, reveal salient differences between regions with regard to the economic or social functions assigned to land use, which lay emphasis on matters of social and economic development. However, these differences do not fully answer questions regarding clearly environmental functions and related issues. In SENSOR REPs, they are addressed through the concept of human pressure, which is relevant when investigating the effects of human activities on environmental functions and which is used, for example, in assessing risks from negative impacts (Global Forest Watch, 2006). This concept assumes that since human activities make use of land and natural resources, intensification, or conversely extensification, is likely to affect the ecosystems and the biophysical functions assigned to land use, irrespective of the nature of drivers which lead to changes in human activities. Active development is likely to exacerbate the threat to the environment and, in general, high levels of human influence usually mean a greater probability of damage to environmental functions and therefore to multifunctional land use.

High pressure regions occur where, for example, important cities concentrate population and economic activities, which encourages change towards more anthropic land uses, e.g., in the form of building development. Conversely, low pressure regions are those where gradual changes in land use have lower societal impetus, as in the case of forest expansion. Favourable economic conditions can accompany either intense or low pressures, indeterminately; they can also create favourable conditions for efficient management of natural resources to promote recovery from overuse.

Socio-economic indicators were necessary throughout the range of intensities, to determine effects that might impact on the environment. Pressure indicators commonly express the intensity of phenomena that are likely to prompt changes in land use, which is measured by the average per surface unit. Population density is a very general pressure indicator which identifies the level of human presence. Pressures connected with economic development are more complicated. The GDP is a key economic indicator, but it is very complex since it ranges widely and includes information on land use, and natural and man-made resources. However, it has no input for measuring resource depletion (Talberth, Cobb & Slattery, 2007). Pressures arising from economic activities need to be illustrated through specific indicators, which focus on certain activities and on the areas which they affect (Plan Bleu pour l'environnement et le développement en Méditerranée, 2002). For example, transport exerts pressures which can be illustrated through traffic flow, but it also has an impact on areas in the vicinity of main transport axes, where commuter traffic is increasing and often leads to important changes in land use. However, even when focusing on high pressure activities, regional averages have to suffice, since it is impractical to downscale pressure indicators to locate hotspots within the NUTS regions.

Attributes and selection of indicators

The detail contained in REPs as a result of applying these ideas depends on how much concentration is given to the various features identified through general socio-economic or pressure indicators. Successive proposals were discussed in SENSOR, although data availability constraints did not allow much leeway in the indicator selection. However, all depended on three types of regional attributes that previous discussions had identified as the most important.

Firstly, the *economic assets of the region* qualify its potential for economic development. Important assets are synonymous with a highly pro-

ductive economy, which generates added value and stimulates further economic growth which, however, often creates sustainability problems. One important requirement is the decoupling of the GDP from demand on resources, otherwise economic growth will also increase pressures on land, natural and human resources, and on capital.
The key indicator revealing regional differences in economic assets is the GDP per inhabitant, which should be expressed in terms of Purchasing Power Standards (PPS), to eliminate price differentials. This indicator can be supplemented by others that are designed to reveal other differences in development processes or may be focused on SENSOR sensitive sectors which are responsible for pressures. Discussions concentrated on basic economic indicators, e.g., unemployment rates, or sectorial indicators.

Besides the GDP by inhabitant and by worker, both expressed in PPS, selected indicators are the activity rate and the unemployment rate, which emphasises structural economic difficulties. These are considered as core indicators in the REPs. They are supplemented by indicators which focus on specific sectors or on main drivers of economic development. With regard to sectors, these are the sectorial share and the evolution rate in employment and in GVA (Gross Value Added); and, for agriculture, the intermediate consumption in fertilisers and the average total gross margin per hectare of Utilised Agriculture Area. The latter indicate the pressures connected with intensive agriculture. The tourism indicators are the accommodation capacity per km^2 or per resident. With regard to main drivers, it was decided to select the proportion of Research and Development expenses in the GDP and the proportion of workers who have reached tertiary education level.

Secondly, a high *level of human presence* may lead to competition in land use, between housing, economic activities and nature conservation. Thus, it can be interpreted more directly in terms of pressures on land uses even when they can be contained through wise management of human activities.

Population density is the key indicator for showing regional differences in human presence. Although this indicator has been criticized, there was no acceptable alternative. For example, it proved unfeasible to take into account not only the permanent population, but also the seasonal population (tourists), or to take into account the fact that human activities are shared between the place of residence and the work place, where pressures can be exacerbated.

However, it was decided to supplement this core indicator of the REPs with two other parameters, in order to reveal changes in human presence and the main causes of such changes: i.e., the annual underlying rate of variation in population numbers, and changes due to births and deaths.

Thirdly, the importance of *urban settlement structure* was recognised because it is essential to identify the presence of urban 'pressure hotspots' within the regions.

The key indicator which was suggested and adopted as a key parameter in the REPs comes from ESPON and is the presence of important Functional Urban Areas (FUAs) in the region, FUAs comprise an urban core and the surrounding municipalities with which it is economically integrated, e.g., via the local labour market. ESPON demonstrated the relevance of the ESDP central assumption, which is that FUAs are key drivers in spatial and economic development in European countries, which results mainly in urban pressure increasing in city centred regions.

This type of attribute seemed to be illustrated by the presence of FUAs. Possibly, this key indicator could be further supplemented by two other indicators, namely the proportion within the regions of high density areas, and the average travel time to the next FUA.

Results

Table 1 gives the final list of indicators which resulted from these discussions. Eurostat indicators were the most appropriate, since they are regularly updated, in contrast with most ESPON indicators.

The latter were only used when there was no corresponding indicator in Eurostat, or to fill gaps in some Eurostat tables. However, when Eurostat indicators were only available for NUTS2 regions, the same values were assigned to all NUTS3 regions within each NUTS2 region. This involves mainly the following indicators which are available only for NUTS2 regions: Research and Development expenses, proportion of employees in the workforce who have reached a tertiary level of education, the proportion of the main SENSOR sectors (agriculture, transport, and energy) in the GDP, and employment levels. For agriculture, indicators involved are the intermediate consumption in fertilisers and average total gross margin per ha of UAA.

The population density and the presence of indicators of FUAs are easy to interpret in terms of pressures on land resources and related functions. They reveal major differences between regions, although important pressures could come from other causes, e.g., highly intensive agriculture in sparsely settled regions.

Table 1. Indicator framework for the SENSOR REPs

Related Attribute	Indicator (core indicator in bold)	Unit or calculation	Source
Economic assets	**GDP/inhabitant in PPS**	In €, index Europe = 100	EUROSTAT or ESPON
		Evolution rate in %	
	GDP/active population in PPS	In €, index Europe = 100	EUROSTAT or ESPON
		Evolution rate in %	
	Activity rate	In % of total population	EUROSTAT or ESPON
	Unemployment rate	In % of active population	
	R & D expenses	In % of GDP	EUROSTAT
	Persons with tertiary level of education	Share in employed persons in %	EUROSTAT
	Employment in SENSOR sectors	Share of each sector in total employment	EUROSTAT
		Evolution rate in % in each sector	
	Gross added value in SENSOR sectors	Share of each sector in % of total GVA	EUROSTAT
		Evolution rate in % in each sector	
	Intermediate consumption in fertilisers	In € per ha of UAA	EUROSTAT
	Average total gross margin per hectare	Index Europe = 100	EUROSTAT
		Evolution rate in %	
	Tourism accommodation capacity	Bed places per inhabitant	EUROSTAT
		Bed places per km^2	
Human presence	**Population density**	In inhabitant / km^2	EUROSTAT or ESPON
	Population change	Annual evolution rate of the population in %	EUROSTAT
	Natural increase of population	Annual evolution rate of the population due to births and deaths in %	EUROSTAT
Spatial settlement structure	**Presence of main functional urban areas**	3 classes of regions	ESPON
	Accessibility to services	Average time travel to next FUA	ESPON
	Importance of low and high density areas	% of households living in densely -, intermediate- and thinly-populated areas	EUROSTAT

Figure 1 emphasises the contrasts revealed by these two indicators[2] between regions of Northern Europe, Central Spain, Central France, Western

[2] The FUA indicators are based on lists of ESPON FUAs having more than 100,000 inhabitants. To distinguish European regions in terms of the importance of major urban settlements, the indicator recognises three types of regions: at first,

Ireland, and Western Greece (where there are few FUAs, or where population densities are low) compared with the 'pentagon' (the area comprising London, Hamburg, Milano, and the Rhine Valley, which is considered as the economic core of Europe) and Eastern Europe and some Mediterranean regions, where population densities are higher and where FUAs are more numerous. However, these two core indicators do not address differences in economic assets, thus there is a risk that, when considered alone, they deliver too simple a message with respect to the aims of REPs.

In practice, all indicators complement each other, and reveal a wide variety of social and economic conditions in Europe when it comes to assessing multifunctional and sustainable land use in European regions.

For example, Figures 2 and 3 show clearly that core indicators related to the economic assets of the regions do not reveal the same spatial pattern as that which emerges from population density indicators. Figure 2 contrasts former Eastern Bloc countries with longer standing EU member states, and in some cases contrasts, within a single country, the capital region with 'peripheral' regions. Figure 3 shows that unemployment rates show some correlation with differences in GDP per inhabitant, but the relationship is not exact. Therefore several indicators need to be considered to identify the most general overall message that they can provide when taken together. Statistical analyses helped to rank the core indicators, in terms of capacity to reveal salient differences between regions, which arise primarily from variations in GDP indexes and in rates of population change. A less important role was played by differences in population density, activity or unemployment rates, and their presence in FUAs.

those having at least one FUA with more than 500,000 inhabitants; then, those without any FUA with more than 500,000 inhabitants but where all together, the FUAs count more than 250,000 inhabitants; and finally, those where all together the FUAs count fewer than 250,000 inhabitants.

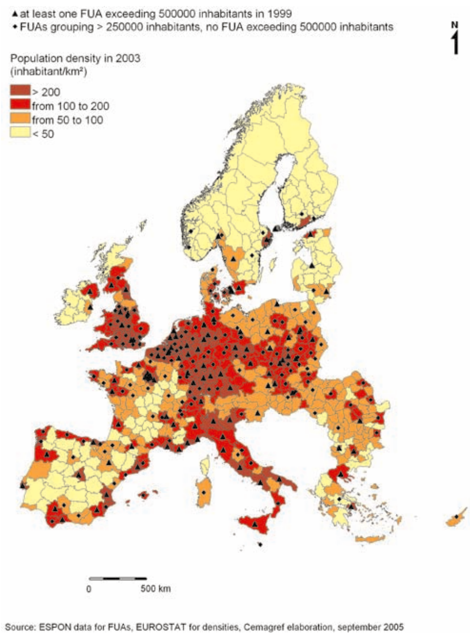

Fig.1. – Population density and presence of main FUAs

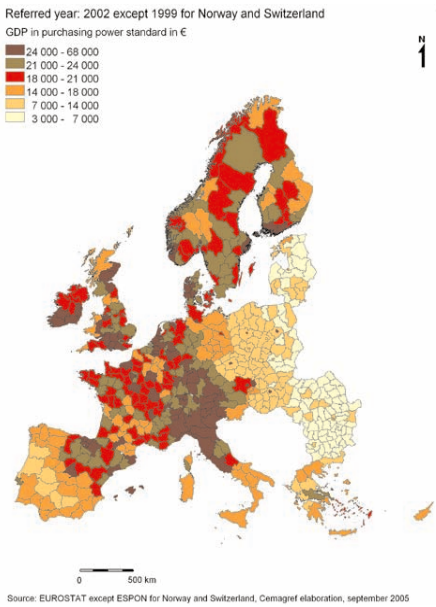

Fig.2.– Regional differences in GDP in PPS/inhabitant

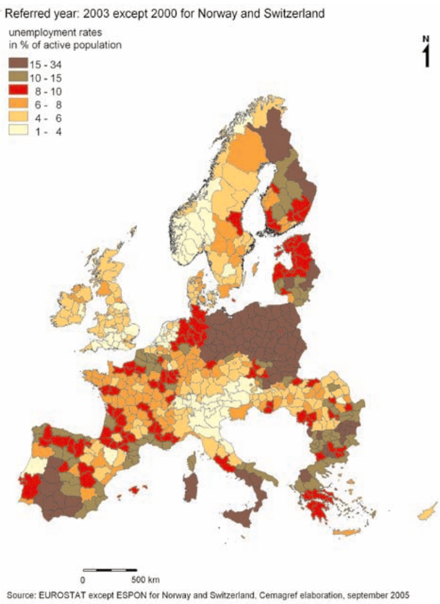

Fig.3.– Regional differences in unemployment rates

4 Conclusions

The challenges in developing REPs were very similar in SENSOR, and in other projects that aimed to address complex issues through common statistical socio-economic indicators. Besides availability of comparable data, it is important to assess the significance of the information provided by indicators against the objectives assigned to the REPs. Their significance extends beyond that directly associated with parameter values related to economic or social phenomena. The main challenge was to select them through their ability to reveal differences which would be relevant in relation to multifunctional land use. Since this topic is not commonly addressed through these indicators, solutions had to be found. They were derived from previous research work, notably ESPON projects, but they emerged above all as a SENSOR framework made it possible to address multifunctional land use. However, the final choice of indicators had still to be discussed between experts, when it came to applying the conceptual approach.

General achievements are in terms of methods to populate SENSOR REPs either with general socio-economic indicators revealing main development trends or with pressure indicators that express the intensity of phenomena that are likely to prompt changes in land use functions. Other achievements concern the preparation of the SRRF, for which a limited set of core indicators was identified. Since they revealed salient regional differences, clustering exercises completed in the SRRF combined them with differences based on bio-physical parameters.

However, a difficulty inherent to any ex ante assessment exercise is that the contrasts in regional contexts, described through the REPs, are those related to the socio-economic status quo or processes present at that time. Changes that arise in the future will possibly reveal other differences from those currently emphasised, which would also be relevant in assessing issues of land use sustainability. In addition, since SENSOR REPs were established in the first year of the project, subsequent advances could lead to a revision of the importance assigned to certain indicators in the REPs. In spite of these limitations, the main lesson drawn from the exercise is that, even when the scope of these REPs was restricted by the shortage of available pan European data, and too few indicators that addressed specifically multifunctional land use, more general social and economic indicators were able to provide useful insights. This was achieved by combining data to elicit fresh information, and by re-using indicators which had proved efficient in other projects, even when their objectives were quite different from SENSOR.

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A Spatial Regional Reference Framework for Sustainability Assessment in Europe

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Abstract

A Spatial Regional Reference Framework (SRRF) has been produced which will allow an efficient assessment of sustainability impact indicators across Europe. In order to achieve this goal, it was necessary to define relatively homogeneous regions, in terms of both biophysical and socio-economic characteristics. The major objective was the integration of these dimensions into European regions that were as uniform as possible. Therefore, in order to retain comparability, it was necessary to use consistent European databases. The spatial framework consisted of three levels, which were necessary to incorporate data on different tiers of spatial aggregation: (1) the INSPIRE Reference Grid, (2) a newly established NUTSx classification, which is a trade-off between administrative European NUTS2 and NUTS3 regions, and (3) the construction of SRRF cluster regions. The last were produced by using a statistical cluster analysis based on a restricted set of important biophysical and socio-economic parameters. 27 cluster regions resulted, which provided a flexible tool for further impact assessment at regional level.

Keywords

European cluster regions, statistical clustering, NUTSx classification, LANMAP2, Spatial Regional Reference Framework (SRRF), primary landscape structure, secondary landscape structure, regional impact assessment

1 Introduction

1.1 Background

Since the late 1980s, sustainable development has become a keynote in EU planning and policy. In general, three main policy dimensions are associated with sustainable development: economic, environmental and social. In order to assess the policy impact within the three dimensions, indicators and guidelines have been developed to provide the basis for in-depth analysis of sustainability impact assessment (CEC 2005). The SENSOR project seeks to identify regional sustainability thresholds, by considering regional differences in the socio-economic and biophysical settings. The analysis required regions that were comparable both in biophysical and socio-economical factors, and at a consistent spatial scale that is practical for European impact assessments. As a consequence, there is a need to identify and delineate spatial units which are relatively homogeneous, in order to be able to assess sustainability impact issues. Previous stratification approaches have mainly been based on biophysical parameters, although they had the potential for including landmanagement and selected socio-economic factors into the frameworks. Some of these classifications are highlighted below and were important sources for meeting the final goal:

- European Landscapes Map described by Meeus (Meeus, 1995): this pan-European landscape typology describes 30 European landscapes. The map integrates not only land form, soil and climate and but also regional culture, habits and history. Its spatial accuracy is not high since it is based mainly on expert-knowledge.
- Environmental Zones (Mücher et al. 2003, Metzger et al. 2005): this classification is derived from climatic, altitude, latitude, slope and oceanity variables. The resulting 84 environmental strata have been aggregated into 13 Environmental Zones. They are useful strata for stratified random sampling of ecological resources.

- LANMAP 2 (Mücher et al. 2003, Mücher et al. 2006): this is a European Landscape Classification that was produced in parallel with the Environmental Classification. LANMAP2 is hierarchical and has four levels. The first level is determined by climate (Environmental Classification) and has eight classes (aggregated), the second level uses climate and topography and has 31 classes, and the third level also includes parent material and has 76 classes. The database contains more than 14,000 mapping units and the minimum unit is 11 km^2. The fourth and final level is determined by climate, topography, parent material and land cover and has 350 landscape types. LANMAP2 already has many applications in the field of environmental stratification, indicator reporting and analysis of changes at the landscape level.

While classical environmental assessment builds upon purely biophysical research at the ecosystem or biogeographic level, most socio-economic studies are based mainly on demographic, economic or policy information. However, landscape scientific research, which once had a purely ecological perspective, is broadening to include wider socio-cultural domains (Naveh & Lieberman 1994; Wascher 2005). The interdependencies that exist between landscape character and the socio-economic context have also been stressed (Peterseil et al. 2004; Wrbka et al. 2004). Therefore, it seems to be a logical step, when defining European regions, to consider socio-economic factors that will help to provide the background for assessing sustainability, sensitivity to change and multi-functionality in the landscape. It is on this basis that an integrated approach for identifying homogenous regions in Europe has been selected. Both bio-physical and socio-economic parameters have been combined into a spatial stratification of land, which is an innovative concept because it is designed to overcome the methodological fragmentation of most current approaches.

1.2 Objective

In the current analysis, the objective is to establish a Spatial Regional Reference Framework (SRRF) for Europe, by stratifying the European land surfaces into relatively homogeneous regions, integrating biophysical, socio-economic and regionally specific characteristics The underlying rationale for conducting a more in-depth regional characterisation is to quantify the high degree of cultural and natural diversity that exists between European regions (Wascher 2005; Mücher et al. 2003). The approach is based upon the following assumptions:

1. regional characteristics determine the scale and scope of impacts on sustainability that have resulted from policy-induced land use changes;
2. environmental and socio-economic profiles are independent of administrative boundaries and define regional coherence and differences across the entire EU;
3. taking regional characteristics into account will facilitate expert assessments (e.g., for the identification of regional thresholds) and stakeholder participation;
4. understanding and addressing these regional characteristics will greatly improve the interpretation of impacts with regard to their likely environmental and socio-economic effects.

2 Methods

2.1 Building up the framework

The smallest spatial unit available for a European-wide assessment of socio-economic and regional administrative aspects is the NUTS2 or 3 level (Official Journal of the European Union, 2003). The Nomenclature of Territorial Units for Statistics (NUTS) was established by Eurostat more than 25 years ago, in order to provide a single uniform breakdown of territorial units for the production of regional statistics for the European Union (http://ec.europa.eu/comm/eurostat/ramon/nuts/introduction_regions_en.html). This information is only meaningful at the level of spatial aggregation, in contrast with the majority of the biophysical aspects, which can be up- or downscaled more easily. Hence, it is necessary to take these NUTS levels into account as the smallest spatial units when looking for homogeneous regions, although there are obvious limitations.

The framework is made up of three levels (Figure 1): Grids with available biophysical information, NUTS regions as the spatial level of available socio-economic information and SRRF clusters which combine all these data. Together, all three levels create an interrelated spatial framework with grid cell level as the smallest unit.

In order to derive homogeneous regions, it is necessary to take into account both spatial integration of biophysical aspects and also how NUTS regions can be used for threshold analysis. Cluster analysis of NUTS regions into SRRF regions is the most appropriate statistical approach, considering the fact that the resultant classes will always be heterogeneous to some degree. The result of the statistical clustering procedure was intended to provide the basis for environmental and socio-economic profiling by identifying relevant and important variables for sustainability assessment.

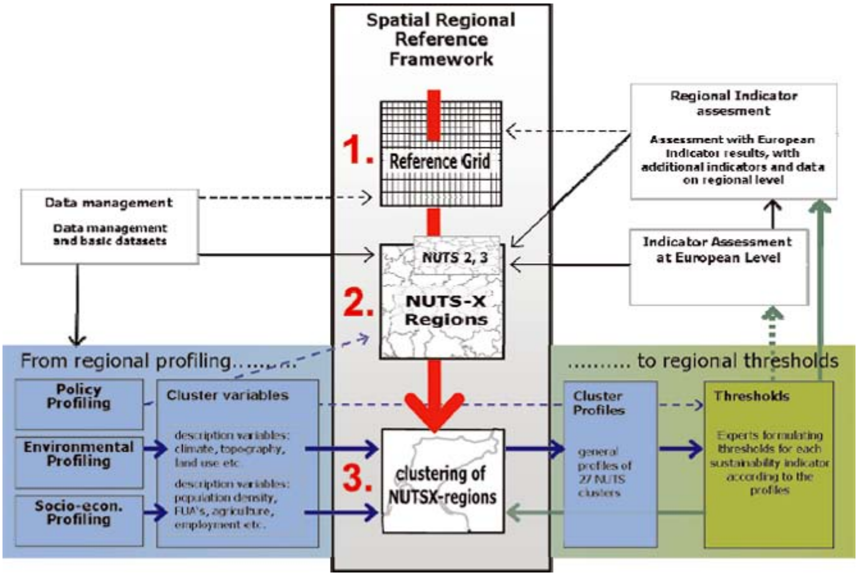

Fig. 1. The three main levels of the Spatial Regional Reference Framework: 1. Reference grid, 2. NUTS-regions and 3. SRRF clusters, creating a related spatial framework with its applicability in the regional assessment.

2.2 Deriving a comparable level of NUTS-regions: the NUTS-X map

It is essential for the NUTS regions to have comparable landscape areas in order to achieve reliable clustering with a degree of homogeneity. In addition, administrative boundaries should be taken into account to ensure that units are comparable for statistical procedures. In order to derive data compatibility between the different variables, the EU common standard of geographical sample grids of the European Environment Agency (EEA) was adopted; using the INSPIRE standards (INSPIRE 2002). The result is termed a NUTSx map and is a selective composition of NUTS2 and 3 units on the basis of the IRENA methodology (EEA 2005).

However, the IRENA project involved only 15 countries, whereas the SENSOR project covers all 27 EU countries, plus Norway, Iceland and Switzerland. Therefore, it was necessary to define the NUTSx level for the additional 12 countries.

Proposals were made on the basis that the chosen level should be comparable to the size of the IRENA regions as regards area, population size and administrative status.

For some of these 12 countries it was difficult to find the appropriate trade-off between the NUTS2 or 3 levels. For example, in Hungary, the Czech Republic and Slovakia, NUTS2 is appropriate on the basis of area or NUTS3 because of population size. In Hungary the choice of NUTS3 could also be made on the basis of its administrative status: the Megyek is the traditional regional division in Hungary, whereas NUTS2 regions are only for statistical purposes. Using the same logic, the opposite choice could be made in Poland. For both countries, the area and population size that are closest to an IRENA region would fall between NUTS2 and NUTS3.

Table 1. - Overview of final NUTS-X regions for the SRRF

Nr	Code	EU 27 + 3	IRENA coverage	Member EU	Average NUTS-X size (km2)	Final Sensor NUTS-X-level	Number of NUTS-X regions	Number of NUTS-2 regions	Number of NUTS-3 regions	NUTS-2 / NUTS-3 ratio	NUTS-2 (km2)	NUTS-3 (km2)	COUNTRY (km2)
1	LU	Luxembourg	Yes	Yes	2565	3	1	1	1	1.0	2565	2565	2565
2	BE	Belgium	Yes	Yes	2752	2	11	11	43	3.9	2752	704	30273
3	NL	Netherlands	Yes	Yes	2920	2	12	12	40	3.3	2920	876	35039
4	DK	Denmark	Yes	Yes	2835	3	15	1	15	15.0	42527	2835	42527
5	IE	Ireland	Yes	Yes	8662	3	8	2	8	4.0	34647	8662	69295
6	AT	Austria	Yes	Yes	9239	2	9	9	35	3.9	9239	2376	83150
7	PT	Portugal	Yes	Yes	13306	2	7	7	30	4.3	13306	3105	93139
8	GR	Greece	Yes	Yes	10280	2	13	13	51	3.9	10280	2620	133642
9	UK	United Kingdom	Yes	Yes	6529	2	37	37	133	3.6	6529	1816	241576
10	IT	Italy	Yes	Yes	14341	2	21	21	103	4.9	14341	2924	301167
11	FI	Finland	Yes	Yes	17083	3	20	5	20	4.0	68333	17083	341667
12	DE	Germany	Yes	Yes	8608	2	41	41	439	10.7	8608	804	352909
13	SE	Sweden	Yes	Yes	21506	3	21	8	21	2.6	56452	21506	451620
14	ES	Spain	Yes	Yes	10208	3	50	17	50	2.9	30024	10208	510402
15	FR	France	Yes	Yes	5681	3	96	22	96	4.4	24788	5681	545340
16	MT	Malta	No	Yes	323	2	1	1	2	2.0	323	162	323
17	CY	Cyprus	No	Yes	9499	3	1	1	1	1.0	9499	9499	9499
18	SI	Slovenia	No	Yes	1678	3	12	1	12	12.0	20135	1678	20135
19	EE	Estonia	No	Yes	8982	3	5	1	5	5.0	44910	8982	44910
20	SK	Slovakia	No	Yes	6060	3	8	4	8	2.0	12121	6060	48484
21	LV	Latvia	No	Yes	10643	3	6	1	6	6.0	63858	10643	63858
22	LT	Lithuania	No	Yes	6405	3	10	1	10	10.0	64050	6405	64050
23	CZ	Czech Republic	No	Yes	5566	3	14	8	14	1.8	9741	5566	77925
24	HU	Hungary	No	Yes	4611	3	20	7	20	2.9	13174	4611	92218
25	BG	Bulgaria	No	Yes	3966	3	28	6	28	4.7	18506	3966	111039
26	RO	Romania	No	Yes	5642	3	42	8	42	5.3	29622	5642	236974
27	PL	Poland	No	Yes	6839	3	45	16	45	2.8	19235	6839	307763
28	CH	Switzerland	No	No	5778	2	7	7	26	3.7	5778	1556	40448
29	IS	Iceland, Island	No	No	104253	3	1	1	1	1.0	104253	104253	104253
30	NO	Norway	No	No	17242	3	19	7	19	2.7	46799	17242	327596
		Average			**11133**		**19**	**9**	**44**	**4.5**	**26311**	**9229**	**159459**
		Total					**581**	**277**	**1324**				

It was decided that for these countries the NUTS3 level should be used in SENSOR.

Choosing NUTS3 prevents dilution of available information by keeping the spatial regionalisation at the most detailed level. If necessary (e.g., if there were to be a change in the availability of information), the NUTSx level could be changed. Table 1 gives an overview of the final NUTSx level used in the cluster analysis.

2.3 Development of SRRF regions

Conceptual Approach

The methodology for developing and profiling homogeneous regions was guided by the hierarchical concept of "primary – secondary – tertiary landscape structure" (O'Neill et al. 1986, Ružicka & Miklos 1990), an approach which tries to assign systematically any landscape attribute to three domains: the biophysical (Primary Landscape Structure or PLS), the land-management / socio-economic (Secondary Landscape Structure or SLS) and planning / policy which is the Tertiary Landscape Structure, or TLS (see Figure 2).

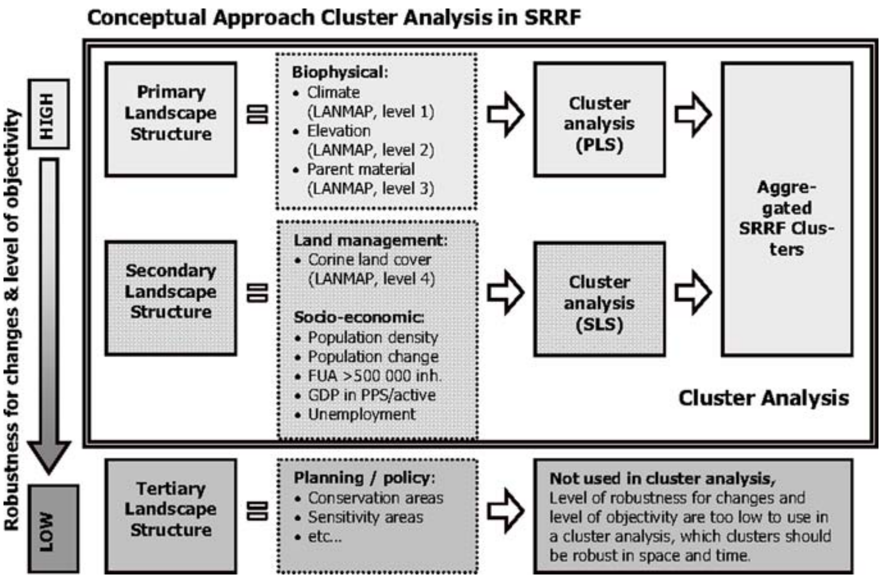

Fig. 2: Conceptual approach for establishing clusters in the Spatial Regional Reference Framework; (FUA = Functional Urban Area, GDP in PPS/active = GDP per worker (active population) in 1999 in purchasing power standards (PPS)

In this concept, parameters which cannot be altered; e.g., climate, topography and bedrock; are the main drivers of land cover and are therefore assigned as PLS.

Landscape change resulting from human interaction with PLS can be rapid; e.g., from forest to pasture; and is therefore at the second hierarchical level. Landscape policy and / or planning and administrative boundaries are often dynamic, but in general their influence is not readily quantifiable. These aspects are assigned to the lowest level of the concept – the TLS.

This approach was chosen to keep the subsequent statistical procedures as simple and transparent as possible. However, it was also decided that the whole classification approach should allow flexibility for any necessary improvements by stepwise integration of additional variables and/or knowledge. Biophysical/socio-economic and land cover data have been clustered in two separate steps. This offers more transparency in separating the results for the biophysical variables from the relatively more dynamic socio-economic and land use management variables (see Figure 2).

The tertiary landscape structure level (the planning / policy domain) is not suitable for a cluster analysis, because the levels of resistance to change and the objectivity are too low.

The next stage was to aggregate the two resulting data sets to form reasonably homogenous clusters within Europe. A matrix of NUTSx regions was therefore constructed, comprising a combination of a PLS / SLS clusters (see Figure 3).

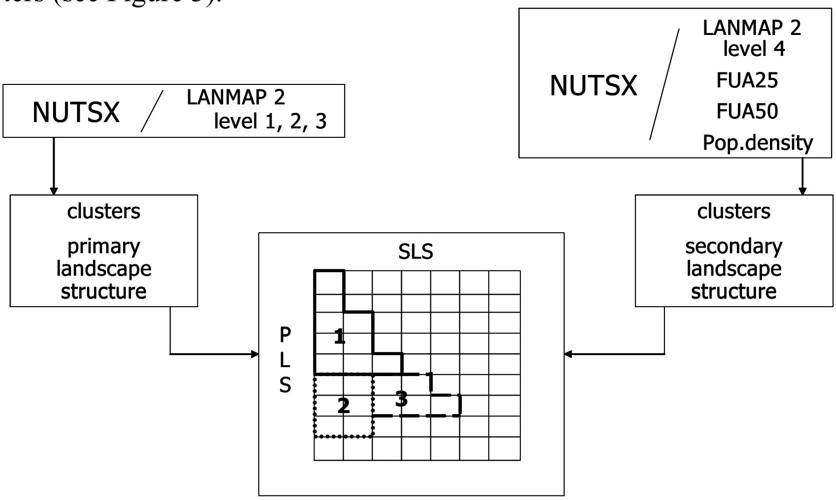

Fig. 3: Concept of aggregating PLS and SLS clusters to SRRF clusters; PLS = Primary Landscape Structure; SLS = Secondary Landscape Structure; SRRF = Spatial Regional Reference Framework

Aggregation of the two sets of clusters was carried out by building a matrix, arranging the clusters according to the relative distance between the cluster centres. Clusters with a small distance between each other, were merged with their neighbours, whereas clusters that were further apart, were grouped separately. In this matrix, columns and/or lines, which represent a given degree of similarity, were joined into one SRRF cluster, but there remained some options for generalising or further dividing some groups.

Methodological Implementation

Input data

To create a meaningful Europe-wide clustering of NUTSx regions, consistent data are essential, therefore only two accepted data sets were used. The biophysical data representing PLS were derived from LANMAP2 (Mücher 2005) and socio-economic data for the SLS were extracted from the ESPON and EUROSTAT database (http://www.espon.eu/; http://epp.eurostat.ec.europa.eu).

All levels of LANMAP2 were intersected in GIS with the NUTSx regions to calculate the percentages of area of the variables for each NUTSx. Since it is generally assumed that coastal influence is important, as is emphasised by many institutions; e.g., the Integrated Coastal Zone Management of the EU (http://ec.europa.eu/environment/iczm/home.htm); the length of coastline per NUTSx region was calculated and incorporated into the cluster input data.

The socio-economic data set, which was proposed by Briquel (2007), consisted of 16 variables which needed to be redefined and re-aggregated. Because several of these attributes showed strong correlations with each other, a selection had to be made. Therefore, the parameters were grouped according to their different information content (demography, GDP & (un-)employment and FUAs). Within each of the groups a Principal Components Analysis (PCA) (Jongman et al. 1995) was carried out, revealing the most significant parameters. The final selection was based on the highest correlation of variables with the resulting axes of the PCA; this is shown in Table 2, as input data for the cluster-analysis.

Because it proved impossible to obtain complete coverage of Europe, there are still gaps in the existing data concerning a few NUTSx regions[1].

[1]The excluded regions are: Las Palmas, Tenerife, Andorra, Bjornoya, the Channel Islands, Cyprus, the Faeroe Islands, Gibraltar, the Isle of Man, Iceland, Jan Mayen, Liechtenstein, Monaco, the Azores, Madeira, San Marino and the Vatican City

Because of this, these regions have not been integrated into the clustering process.

Table 2. Selected variables for cluster-analysis

PLS		
LANMAP2	climate	Alpine North % area
		Alpine South % area
		Arctic % area
		Atlantic Central % area
		Atlantic North % area
		Boreal % area
		Continental % area
		Lusitanian % area
		Mediterranean Mountains % area
		Mediterranean North % area
		Mediterranean South % area
		Nemoral % area
		Pannonian % area
		Steppic % area
	topography	lowland % area
		hills % area
		mountains % area
		high mountains % area
		DEM alpine % area
	parent material	river alluvium % area
		marine alluvium % area
		glaciofluvial deposits % area
		calcereous rocks % area
		soft clayey materials % area
		hard clayey materials % area
		sands % area
		sandstone % area
		soft loam % area
		siltstone % area
		detrital formations % area
		crystalline rocks and migmatites % area
		volcanic rocks % area
		other rocks % area
		organic materials % area
		unclassified (urban/water/ice) % area
		coastline % perimeter

SLS		
ESPON / EUROSTAT		population density 2003
		population annual change rate % 1998-2003
		activity rate in %
		index of GDP in PPS/active in €
		unemployment rate 2003
		FUAs with > 500000 habitants population in thousands
LANMAP2	land cover	artificial surfaces % area
		arable land % area
		intertidal flats % area
		forest % area
		heterogeneous agric. areas % area
		open spaces with little or no vegetation % area
		pastures % area
		permanent crops % area
		shrubs & herbaceous vegetation % area
		waterbodies % area
		wetlands % area

Cluster Analysis

The aim of the cluster analysis was to generate groups of NUTSx regions to enable the development of sustainability profiles, and the calculation of regional indicators and thresholds.

The resulting NUTS groups were presented as maps (see Figures 4, 5 and 6). A stepwise clustering method, as described in the conceptual approach, delivered the best results and generated 27 clusters; with variance being kept as low as possible *within* clusters, and as high as possible *between* clusters.

Clustering PLS and SLS

The structure of the input data (building on experience from the draft calculations with SPSS 12.0) led to the conclusion, that K-Means clustering using Euclidean distance was the most appropriate clustering technique. This procedure is suitable for calculations with metric data. The main advantage, compared to the hierarchical method, is that objects which are part of one cluster can be removed and allocated to another in the following iterative step. Iteration is done as long as the optimal cluster solution is found and the sum of variation square is minimised within the clusters (Janssen & Laatz, 2005).

In this method, the number of clusters has to be specified beforehand. It was therefore necessary to run some trials in order to achieve a tenable result. A point was reached when it became unproductive to enlarge the number of clusters, because those with many NUTSx regions did not split up, but a significant number of single NUTSx regions were created that formed a cluster on their own. Based on the results of the trials, it was found that 25 PLS cluster and 20 SLS cluster satisfactorily represented heterogeneity at the European level. This resulted in the avoidance of isolated individual clusters with fewer than 3 NUTSx regions (spatial homogeneity), while retaining the ability to show differences at the highest possible level.

Aggregation to Spatial Regional Reference Framework Clusters

After clustering NUTSx regions according to their PLS and SLS, it was necessary to join them together and form relatively homogenous regions throughout Europe. Each NUTSx region combines two different clusters (one PLS, one SLS). The cluster results created the possibility of constructing a matrix with PLS in rows and SLS in columns (Figure 3).

Distances between the cluster centres show how strongly clusters are linked. Small distances indicate a greater similarity and they were therefore grouped next to each other, and clusters which differed more were arranged further apart. Some clusters have a connection with several groups and it was therefore necessary to use expert knowledge in order to find the appropriate allocation. Depending on what degree of detail the regional profiles required, it was possible to formulate around 100 regions (the number of existing combinations) or to generalise them if required. The first attempt defined 30 groups which appeared to show clear differences between regions, from the European perspective.

3 Results

3.1 Regional Clusters

Primary Landscape Structure (PLS)
Basically, 25 clusters could be identified from the analysis of PLS. In Figure 4, a map shows the classification of the NUTSx regions, based on biophysical variables. One result is the cluster centre values, which are the calculated mean of the variables of the NUTSx regions belonging to the cluster, and provide the basis for describing each one.

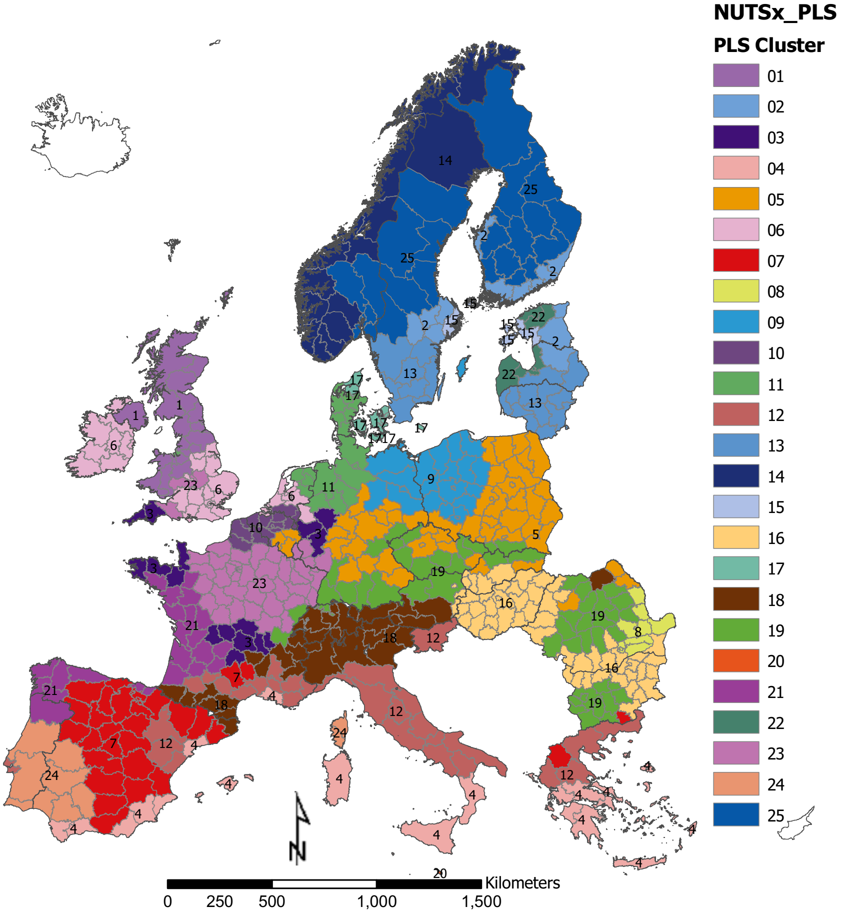

Fig. 4. PLS cluster regions of Europe

Table 3: ANOVA analysis of PLS clusters, variables which are significant in forming the clusters are highlighted in orange (higher significance) and blue (lesser significance)

		ANOVA				
		Cluster		Error		
		mean square	df	mean square	df	F
Climate	Alpine North	2,864.36	24	16.496	539	173.635
	Alpine South	4,387.63	24	83.952	539	52.264
	Arctic	0.144	24	0.095	539	1.523
	Atlantic Central	25,831.14	24	88.086	539	293.248
	Atlantic North	9,262.43	24	79.588	539	116.38
	Boreal	11,564.55	24	33.038	539	350.035
	Continental	26,076.77	24	181.415	539	143.741
	Lusitanian	6,162.97	24	40.137	539	153.548
	Med. Mountains	2,257.71	24	65.675	539	34.377
	Mediterranean North	4,553.53	24	112.339	539	40.534
	Mediterranean South	6,025.18	24	75.218	539	80.102
	Nemoral	8,648.57	24	27.826	539	310.808
	Pannonian	12,760.92	24	64.697	539	197.24
	Steppic	2,180.02	24	17.795	539	122.507
topography	Coastline	10,365.03	24	378.589	539	27.378
	intertidal flats	4.812	24	1.054	539	4.564
	hills	17,101.79	24	337.414	539	50.685
	lowland	21,717.98	24	269.544	539	80.573
	mountains	12,884.47	24	213.174	539	60.441
	high mountains	2,176.26	24	33.442	539	65.075
	alpine (DEM)	1.468	24	0.176	539	8.357
parent material	river alluvium	1,520.19	24	137.783	539	11.033
	marine alluvium	175.364	24	23.119	539	7.585
	glaciofluvial sediments	20,445.34	24	146.891	539	139.187
	calcareous	6,297.39	24	176.024	539	35.776
	soft clayey	988.273	24	132.27	539	7.472
	hard clayey	28.924	24	12.535	539	2.307
	sands	4,024.47	24	149.964	539	26.836
	sandstone	212.63	24	43.958	539	4.837
	soft loam	8,247.91	24	219.202	539	37.627
	siltstone	4.734	24	1.18	539	4.012
	detrital formations	67.408	24	28.359	539	2.377
	crystalline	10,267.62	24	273.085	539	37.599
	volcanic	55.303	24	21.708	539	2.548
	other rocks	176.62	24	35.033	539	5.042
	organic materials	85.299	24	14.061	539	6.066
	unclassified	3.757	24	0.824	539	4.559

The ANOVA analysis (Table 3) provides information about the significance of attributes for the classification. The high F-values indicate that climatic variables are the most important distinguishing feature on a broad scale. However, topography and parent material are discriminators for classifying regions within.

Secondary Landscape Structure (SLS)

On the basis of the input data, the NUTSx regions were assigned to 20 clusters. Figure 5 presents the European SLS clusters. The ANOVA analysis presented in Table 4 reveals that land cover is mainly responsible for creating clusters; other socio-economic variables play a less important role.

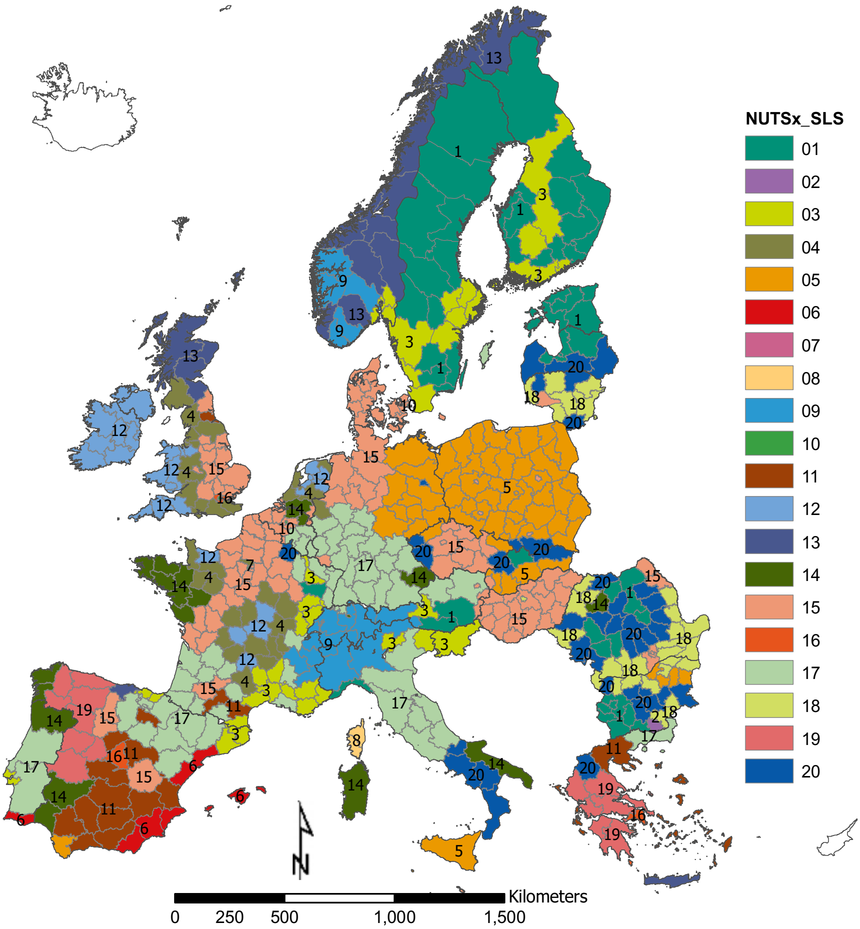

Fig. 5. SLS cluster regions of Europe

Table 4. ANOVA analysis of SLS clusters, variables which are significantly forming the clusters are highlighted in orange (higher significance) and blue (lesser significance)

ANOVA	Cluster		Error		
	mean square	df	mean square	df	F
pop.density	796.951	19	10.222	544	77.968
pop.change	9,455.269	19	178.736	544	52.901
activity rate	222.055	19	36.432	544	6.095
GDP	3,296.948	19	65.859	544	50.060
unemployment rate	5,188.289	19	103.909	544	49.931
FUA	1,300.655	19	112.421	544	11.570
artificial surfaces	2,056.768	19	10.620	544	193.670
arable land	30,142.035	19	166.882	544	180.619
intertidal flats	1.526	19	1.173	544	1.301
forest	23,136.604	19	127.593	544	181.331
heterogeneous agric. areas	3,513.123	19	76.378	544	45.996
open spaces (unvegetated)	2,523.869	19	17.245	544	146.352
pastures	11,369.805	19	43.295	544	262.615
permanent crops	136.243	19	19.706	544	6.914
shrubs & herbaceous vegetation	5,515.312	19	53.432	544	103.221
waterbodies	4.000	19	1.604	544	2.494
wetlands	5.201	19	1.379	544	3.772

Aggregation to SRRF clusters

Each NUTSx region belongs to one PLS and one SLS cluster. In total, there are 107 different combinations of clusters; those most alike are grouped next to each other. In the matrix, lines indicate where aggregations are statistically not feasible.

The method is flexible because it combines a statistical base and still allows for expert judgement. Depending upon which level of detail seems to be necessary, aggregation can be adjusted.

When working with the SRRF clusters in terms of applications, it was apparent that the first result of the "scientific" clustering had limitations, because policy makers require spatial coherence in order to reflect regional character. Therefore, in a second phase SRRF clusters were modified, using the PLS / SLS matrix based on the following pre-defined rules:

Individual or groups of identical SRRF clusters which lie more than 350 km apart were treated as follows:

- cluster regions with up to three NUTS regions were reallocated according to the matrix, or in exceptional cases to neighbouring classes ('changes with boundaries');

- if there were more than three NUTS regions then these were allocated to a separate cluster ('split-up');
- urban clusters, e.g. Paris, London, Berlin, Madrid, ('city rule') were allocated to surrounding clusters to keep consistency, because other significant conurbations were not included, e.g. Amsterdam;

Application of these rules resulted in 27 SRRF cluster regions (Figure 6). The reallocation of the outline of NUTS-X regions is improving the socio-economic cohesion, and is therefore easier to interpret and communicate to policy makers.

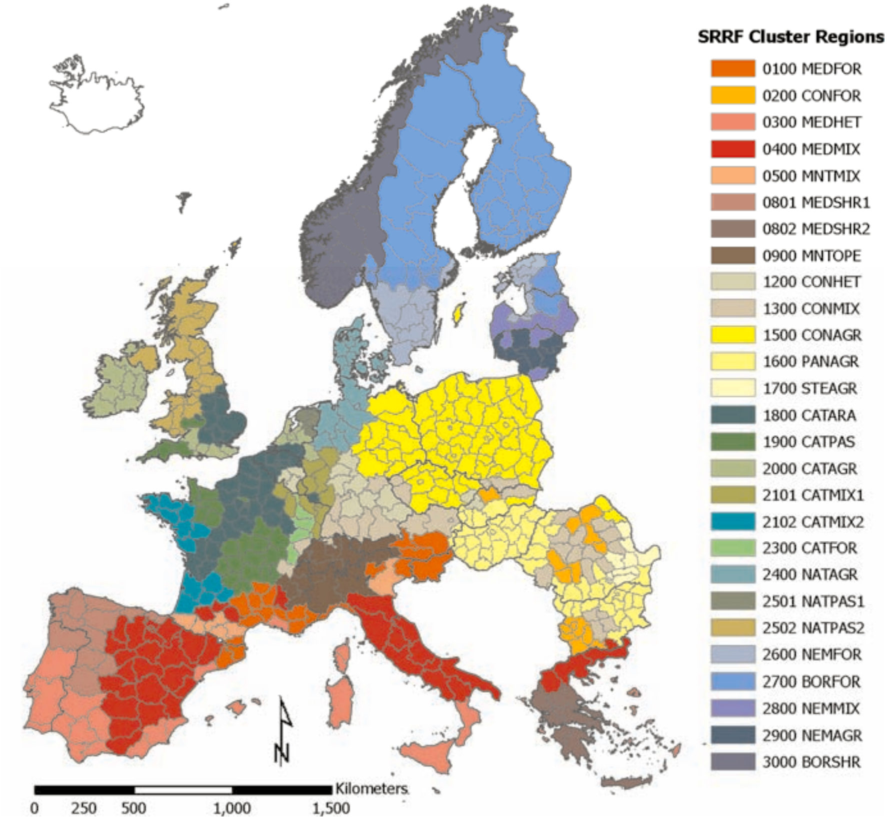

Fig. 6. Final SRRF cluster regions after implementing the post-processing procedure; identifiers and abbreviations of the SRRF cluster regions are presented in the adjacent legend.

4 Discussion

For the SENSOR project it is essential to find appropriate reference units for which thresholds and limits can be defined. As the impact assessment is based on three pillars of sustainability (economic, environmental and social), the development of these reference units has to be based on variables which represent all policy domains. Hence the approach described above.

Previously developed landscape classifications such as Environmental Zones (Metzger et al., 2005) and LANMAP2 (Mücher et al., 2006) are more appropriate for ecological investigations.

For a Europe wide classification it is important to rely on consistent data. Therefore the major data sources have been identified as LANMAP2 (Mücher et al. 2006) and the ESPON data base. Biophysical and land cover data were available on as grid or as vector data. But socio-economic parameters, e.g. GDP per capita, population density, unemployment rate etc., were in most cases available for administrative units (NUTS-regions). Therefore the interface of NUTS-X regions was developed in order to have the possibility to combine all data sets. This is one of the crucial points of the SRRF. On the one hand, NUTS-X show several limitations like different size, heterogeneity and different composition of land cover classes, but on the other hand, European projects and administrations are almost solely using these units (Official Journal of the European Union, 2003).

There remains a major constraint in that some socio-economic data from LANMAP for some NUTSx regions were not available for incorporation into the SRRF. A possible solution is to find other data-sources which offer comparable information and to integrate these data into the cluster regions. From a political and pragmatic point of view, this could be an administratively useful first step towards a classification system covering the whole of Europe. Other European institutions, e.g., the EEA may not find the SRRF as suitable, because environmental questions may need other spatial units.

The clustering and profiling for threshold analysis is based on primary and secondary landscape structure. Only the SLS is expected possibly to change in future, leaving the PLS as a robust basis of the current clustering method. In the timescale of the SENSOR project small administrative changes in NUTS boundaries will have limited effects on the clustering results. Major NUTS changes could influence the final clustering (e.g., new grouping of two NUTS regions, which are now in two different clusters). Since the original PLS and SLS values are known it is possible to regroup the new regions manually, with expert knowledge, as has been carried out in this version.

Another possible improvement would be to update the data. The ESPON data used covered the years 1999 / 2000, whereas land cover data were derived from CORINE 1990. Calculating a cluster-analysis with newer data may also result in slight changes. However, they are not expected to cause major re-arrangements of cluster regions since the change in land cover between the year 1990 and 2000 is relatively small (http://terrestrial.eionet.europa.eu/CLC2000/changes).

5 Conclusion

The SRRF can be considered as the first real attempt to integrate biophysical, socio-economic and regional specific characteristics into a robust spatial reference framework. It provides the basis for regional indicator assessment and acknowledges the heterogeneity of European geography and cultural identity. It is flexible and can be re-arranged if future generalisation, or major changes in boundaries and land use so require. Updating of input data and statistical improvements will be the main future tasks if the SRRF stays in use after the project-period of SENSOR.

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Requirements for data management and maintenance to support regional land use research

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Abstract

SENSOR is dependent on sufficient reliable and accurate data that have to be provided and shared by the partners within the project. Access to reliable and harmonised data across Europe is a fundamental precondition for realisation of the SENSOR project. The current chapter describes basics concerning geo-spatial data types and formats, system architecture and database technologies, interoperability standards, including the INSPIRE principles, data warehouse and GeoPortal technologies. Further some information on spatial data mining, on data policies and related legal aspects and the SENSOR approach for spatial data handling are provided.

Keywords

Spatial data management, land use, INSPIRE, spatial data mining

1 Introduction

The quality of examining landscape related phenomena like sustainability impact assessment for landscape multifunctionality as achieved within SENSOR is dependent on sufficient reliable and accurate data that have to be provided and shared by the partners within the project. A proper geospatial data management and data sharing system including metadata reporting, data retrieval, data viewing, data upload and download is the backbone of landscape related research.

Geographic Information Systems are built using formal models that describe how objects are located in space. Every geographical object or phenomena can basically be represented by a point, line or polygon – plus some attributes describing the object. Geographical data are referenced to locations on, below or above the earth's surface by using a standard reference system. There are at least two fundamental different ways of representing geographic information: vector representation and raster representation (Figure 1).

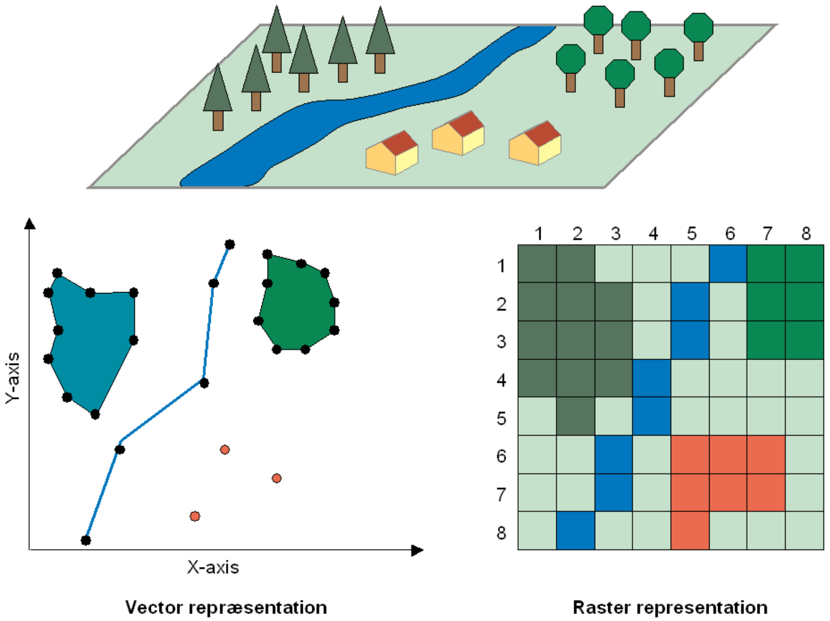

Fig. 1. Vector versus raster representation

Vector is a data structure, used to store spatial data. Vector data is comprised of lines or arcs, defined by beginning and end points, which meet at nodes. The locations of these nodes and the topological structure are usually stored explicitly. Features are defined by their boundaries only and curved lines are represented as a series of connecting arcs. Vector storage involves the storage of explicit topology, which raises overheads, however it only stores those points, which define a feature, and all space outside these features is 'non-existent'.

Raster is an alternative method for representing spatial data. Each area is divided into rows and columns, which form a regular grid structure. Each cell must be rectangular in shape, but not necessarily square. Each cell within this matrix contains location coordinates as well as an attribute value. The spatial location of each cell is implicitly contained within the ordering of the matrix, unlike a vector structure, which stores topology explicitly. Areas containing the same attribute value are recognised as such, however, raster structures cannot identify the boundaries of such areas as polygons. Within the SENSOR community we have to use as well vector as raster based spatial information. Generally, it can be troublesome to use a mixture of data models, but we have to rely on available data. You can transform the data from raster to vector and vice versa but generally not without loss in quality.

Geospatial data have both spatial and thematic properties. Conceptually, geographic data can be divided into two elements: entities and attributes. GIS have to be able to manage both elements, and this defines the overall requirements to the database technology behind.

We propose a definition of a spatial database system as a database system that offers spatial data types in its data model and query language and supports spatial data types in its implementation, providing at least spatial indexing and spatial join methods. Spatial database systems offer the underlying database technology for geographic information systems and other applications.

The Open Geospatial Consortium (http://www.opengeospatial.org/) is a global key player working for interoperability between various database systems. The requirements for implementations of spatial databases are described in the implementation specifications for SQL (Open Geospatial Consortium, 2005). This part of OpenGIS® Simple Features Access (SFA), also called ISO 19125, is to define a standard Structured Query Language (SQL) schema that supports storage, retrieval, query and update of feature collections via the SQL Call-Level Interface. Open Geospatial Consortium allows three different approaches: a) the normalised geometry schema, b) the binary geometry schema, and c) the geometric data type implementation. Thus the database software suppliers have three different ways of handling spatial data in (object-) relational database systems. Oracle, Informix and DB2 have all developed versions based on SQL with geometric data types. The open source databases PostgreSQL and MySQL have also developed versions with geometry data types. However, Microsoft SQL Server does not have spatial data types.

To allow merging and combining different Geospatial data a common coordinate system is required. The content of the curved surface of the Earth is transferred to a flat plane by a projection. Mapping of ellipsoidal and spherical coordinates to plane coordinates cannot be performed without distortion in a plane coordinate system. Distortion can be controlled, but not avoided. Various projections exist to perform such a transfer to reduce distortion in certain ways: among them conic projections (e.g. the Lambert projections), transverse cylindrical projections (e.g. Mercator projections) or plane coordinate projection.

The ellipsoid's properties describing size, shape, position and orientation is summarised as "Datum". To map entire Europe, today the European Terrestrial Reference System 1989 (ETRS89) is committed as the geodetic datum.

The ETRS89 Transverse Mercator Coordinate Reference System is recommended for pan-European mapping at scales larger than 1:500 000. For pan-European conformal mapping at scales smaller or equal 1:500 000 the ETRS89 Lambert Conformal Conic Coordinate Reference System is recommended. With conformal projection methods attributes such as area will not be distortion-free. For pan-European statistical mapping at all scales or for other purposes where true area representation is required, the ETRS89 Lambert Azimuthal Equal Area Coordinate Reference System (ETRS-LAEA) is recommended. The Lambert Equal Area projection is recommended for use in the SENSOR project.

2 Data Infrastructure: Principles of Distributed GIS Technology

Developing a common data infrastructure requires some degree of standardisation among the various data sets. Although, the standards of interest to the SENSOR project are not static but will evolve during the project period as technology changes, the draft specifications of the INSPIRE initiative on architecture, standards and metadata are the main guidelines for this task (INSPIRE, 2002 a). Based on this foundation, an overall frame for the data infrastructure including Web-based catalogue services enabling participants to discover and download appropriate data for their work will be designed and a prototype developed (Figure 2).

The main aim of the SENSOR Data Management System is to support the project partners concerning data handling. To do this the system will include the following components

- Data Warehouse
- Geoportal (Clearinghouse mechanism)
- Metadata reporting system
- Upload and download of data

- Pre- and post processing tools

Besides these IT components the SENSOR Data Management system contains a defined set of Core data and a SENSOR Data Policy.

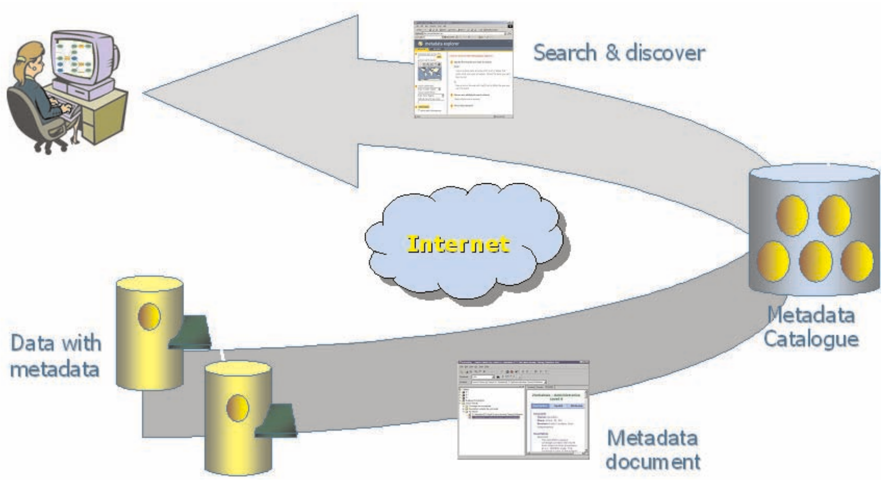

Fig. 2. The Data Management System from a user's point of view.

GIS technology is evolving beyond the traditional GIS community and becoming an integral part of the information infrastructure in many organisations. The unique integration capabilities of a GIS allow disparate data sets to be brought together to create a complete picture of a situation. Thus organisations are able to share, coordinate, and communicate key concepts among departments within an organisation or among separate organisations using GIS as the central Spatial Data Infrastructure. GIS technology is also being used to share information across organisational boundaries via the Internet and with the emergence of Web services. However, other obstacles like for example lack of semantic interoperability may impede the use of information.

An open GIS system allows for the sharing of geographic data, integration among different GIS technologies, and integration with other non-GIS applications. It is capable of operating on different platforms and databases and can scale to support a wide range of implementation scenarios from the individual consultant or mobile worker using GIS on a workstation or laptop to enterprise implementations that support hundreds of users working across multiple regions and departments. An open GIS also exposes objects that allow for the customisation and extension of functional capabilities using industry standard development tools. The current chapter will describe some of the most important elements of distributed GIS, as we will use the concept in SENSOR.

2.1 Standards and Interoperability

Interoperability and open architectures are core requirements for state of the art implementations of IT solutions (Klopfer, 2006). Service oriented architectures based on a commitment to use open standards enables a system of component based building blocks, which can be chosen, run and maintained according to their best match of user requirements, independent of vendor solutions or storage models.

Standards define the common agreements that are needed to achieve interoperability between IT components (Figure 3). Standardisation bodies like ISO or CEN are developing de jure standards, whereas organisations like the Open Geospatial Consortium (OGC) develops specifications that by a consensus process and their common acceptance become de facto standards. Several ISO TC/211 standards are of high importance for building Spatial Data Infrastructures. Besides the ISO Standards the Open Geospatial Consortium (OGC) has developed implementation rules to ensure interoperability. Products and services compliant to OpenGIS interface specifications enable users to freely exchange and apply spatial information, applications and services across networks, different platforms and products.

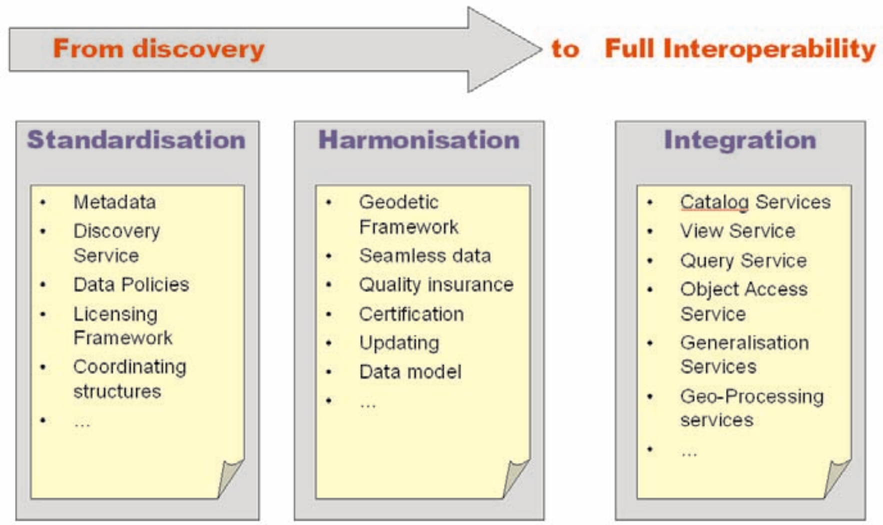

Fig. 3. Ways towards a spatial information infrastructure (INSPIRE, 2002c)

Besides these GI related standards, a geospatial data infrastructure is built on general IT standards like XML (extensible Mark-up Language, SOAP (Simple Object Access Protocol) and WSDL (Web Services Description Language). This is important because GI systems are not longer isolated stand alone systems, but nowadays integrated in the general IT infrastructures. Besides, a basic foundation for all data related work in an EU-funded project like SENSOR is the draft INSPIRES principles (INSPIRE, 2002 a).

2.2 Data Warehouse Architecture

A Data Warehouse is defined as a subject-orientated, integrated, time-variant, non-volatile collection of data that support the decision-making process in an organisation (ESRI, 1998). In general a Data Warehouse is a large database organising data from various sources in a repository facilitating query and analysis. The database has to be structured and contain key data, for search and retrieval. The spatial data warehouse in SENSOR responds to several needs. First we have to realise that the SENSOR project involves 35 partners from many countries, and the data sources are very widely spread. The main task for the central database is to facilitate access to data for all partners. Most common data sets should be added to the Data Warehouse and harmonised so they match with the overall system architecture and the geo-reference characteristics and data quality standards. Data downloaded from EuroStat, ESPON, or the European Environment Agency are not usable at once, but must be adapted in various ways – first of all due to differences in the database keys used.

2.3 GeoPortals and Clearinghouses

Efficient use of geographic information assumes access to documentation that describes origin, quality, age, ownership and suitability for certain purposes. This associated information is referred to as metadata (see paragraph 2.4). A key component of any spatial data infrastructure is a catalogue with metadata that can be used in searching for data considering geometric data content, geographic location, time and thematic attributes.

Technically the word portal refers to a web site acting as an entry point to other web sites (Tait, 2005). An extended definition of a GeoPortal will be a web site that represents an entry point to sites with geographic content. Spatial portals were developed as gateways to SDI initiatives and served as contact point between users and data providers. The GeoPortal allow users to search and browse between huge amounts of data. One of the earliest attempts to develop a Geoportal was the US Federal Geographic Data Committee's Clearinghouse, in Europe the INSPIRE proposal resulted in the development of a European Geoportal (Bernard et al., 2005).

Geoportals can be divided into two groups: Catalogue Geoportals and Application Geoportals (Tang and Selwood, 2005). Catalogue portals create and maintain indexes describing available information services. Catalogue portals are useful when they provide information to a wide variety of services, data providers and user groups. Application portals combine information services into a Web based mapping application that generally focuses on a particular task. Their target community is well defined and they provide efficient access to data and functional services, which the portal manager selects to meet the user's needs. In the SENSOR project a combination between Catalogue and Application Portal is used in order to support both the data and the application side.

The publishing process is the most important part – without any metadata it is impossible to carry out a proper search for data. Publishing comprises addition, modification and deletion of metadata. The SENSOR project has focused much on this effort and a web based metadata publishing / reporting system has been available since August 2005.

Geoportals are built using the World Wide Web infrastructure technology and GIS software. The front end typically sits on top of an Internet Map Server that delivers the services. A Geoportal contains three components: Web Portal, Web services and Data Management. Table 1 describes the components, their relationships between each other and the standards and technologies they are built upon.

Table 1. Geoportal architecture (After Tait, 2005)

Components	**Elements**	**Environments**	**Functions**
Web Portal	Web site	HTML, HTTP, XML, XSL, JSP, ASP	Search, View, Publish, Admin.
	Web controls	Java beans, .NET	Query, Map, Edit
Web services	Geo Web services	XML, SOAP, WSDL, WMS, WFS, GML	QUERY, Render, Transaction
Data Management	RDBMS		Vector
		SQL	Raster
	Data		Tabular

2.4 Metadata

Electronic searching and exchange of metadata require standardisation. Metadata must follow the ISO 19115 standard for metadata. Since 1994, ISO/TC211 (http://www.isotc211.org/) has been working to establish a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth. ISO 19115 Geographic Information - Metadata is a part of the family of TC211 standards and it defines the term METADATA as "data about data". The objective of ISO 19115 is to specify a structure for describing digital geographic data, and the ISO standard on geographic information has quite recently been adopted by CEN the European Standard Organisation.

SENSOR consortium realised from the very beginning, that in order to build a strong spatial data infrastructure and to establish integrity and consistency of all data, metadata would be crucial. Metadata and metadata servers enable users to integrate data from multiple sources, organisations, and formats. Metadata for geographical data may include the data source, its creation date, format, projection, scale, resolution, and accuracy.

Due to the fact that SENSOR end user is the European Commission, it seems reasonable to take outset in existing metadata standards within the Commission. At first, we therefore took a look on the metadata profile from the EEA (European Environmental Agency) as an initial metadata set. The EEA metadata profile builds on the principles in ISO 19115 as well as INSPIRE. Currently, a Metadata Core Drafting team is working on a detailed metadata specification for INSPIRE. The attribute set was reduced for SENSOR in order to increase acceptance among SENSOR data deliverers to fill out the forms completely. The metadata set shall fulfil all needs within the project to fully inform all team members about the content of the data sets. The metadata is furthermore a precondition to assess the usability of the respective data.

Therefore some additional attributes, which are not considered by ISO 19115- standard, but seem to be important, have been added. The most important among them are the fields containing thematic statistical information (e.g. demographic or economic data based on administrative entities like NUTS-Regions) and further content regarding spatial characteristics (e.g. land use classes, elevation, terrain shape, environmental pollution).

Metadata for single data sets can be stored within a metadata-XML-file via ESRI's ArcCatalog in several different style sheets: among them the US-standard “FGDC” structure and the “ISO”-style sheet. Despite the guideline to use ISO-structure we recommend to use the ArcCatalog default metadata editor and FGDC style sheet, which considers FGDC structure, as this is the only way to allow storage of attribute data information (ISO has the disadvantage that no attribute information integration is available within this structure). We apply a special ISO-metadata version, by allowing information about the attribute fields (name and data type). The metadata copied to the SENSOR metadata base can be overwritten at any time. Thus it is recommended to obtain the metadata first from XML-files – for easily including of geodetic information - and to correct or extend the entries afterwards if necessary.

3 SENSOR Data Management System Design

The overall objective of the SENSOR Data Management System is to support all partners to get access to data from various sources as well as data produced within the SENSOR project (Figure 4). The first element in the SENSOR Data Management System is the Metadata Publishing System aimed at reporting metadata for all data related to the SENSOR project. Parallel to the metadata reporting the application facilitates the upload of data to the central server. Closely related to the upload procedure is a checking tool for tabular data regarding geo-reference code (frequently a NUTS-code). Finding and discovering data is provided through a retrieval system based on metadata keywords for the entire data set collection and provided through ESRI's Metadata Explorer.

3.1 SENSOR Data Warehouse

The main component in the SENSOR Data Management system is the Data Warehouse storing pre-processed spatial data with associated metadata (fig. 4). All common data used in the SENSOR project as well as all data produced by SENSOR will be available from the Data Warehouse.

The Data Warehouse is based on state-of-the-art database technology using ArcSDE 9.2 from ESRI - providing a gateway for storing, managing, and accessing spatial data in any of several leading RDBMS from any ArcGIS application. It is a key component in managing a shared, multi-user Geodatabase in a RDBMS. Currently ArcSDE supports the following relational databases: Oracle, IBM DB2 Universal Database, IBM Informix Dynamic Server, and Microsoft SQL Server. Within SENSOR the underlying relational database system will be Microsoft SQL Server 2005.

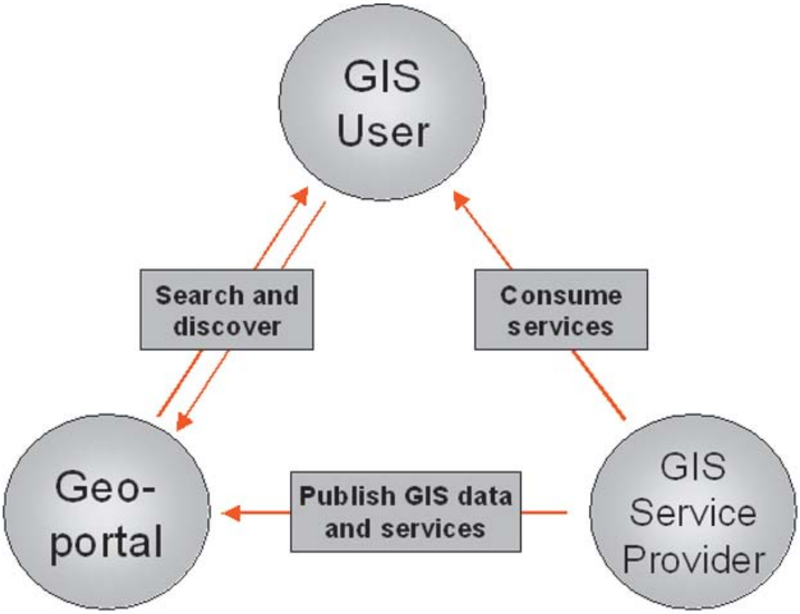

Fig. 4. The relationships between Geoportal, user and service provider (After Tang & Selwood 2005).

Spatial data in the SENSOR project are stored in ArcSDE as either vector features or as raster data sets along with traditional tabular attributes. Topology – the spatial relationships between geographic features – is fundamental to ensuring data quality (ESRI, 2005; Silvertand, 2004). Topology in ArcSDE is implemented as a set of integrity rules that define the behaviour of spatially related geographic features and feature classes. Topology is used to manage the integrity of coincident geometry between different feature classes – for example to check if the coastlines and country boundaries are coincident. The various components of the SENSOR Data Management System (Figure 5) is further described below.

3.2 Input – The SENSOR Metadata Publishing and Upload Application

The SENSOR Metadata Publishing System was developed as Web based Java application as the first part of the SENSOR Data Management System. The purpose was to give the SENSOR community tools for uploading various NUTS-related data and generic geospatial data to the Data Management System. To ensure high convenience for metadata upload the system has a graphical user interface (GUI) guiding the user easily through the application offering several forms with pull down menus just to click an entry among alternatives and some free entry fields for individual text.

A final upload of geospatial data or tabular data with spatial reference is possible only after all metadata have been entered completely. Additional features of this application are automated data integrity checking and a (preliminary) basic data retrieval tool tracing the metadata of the entire geospatial data collection for certain files related to certain keywords.

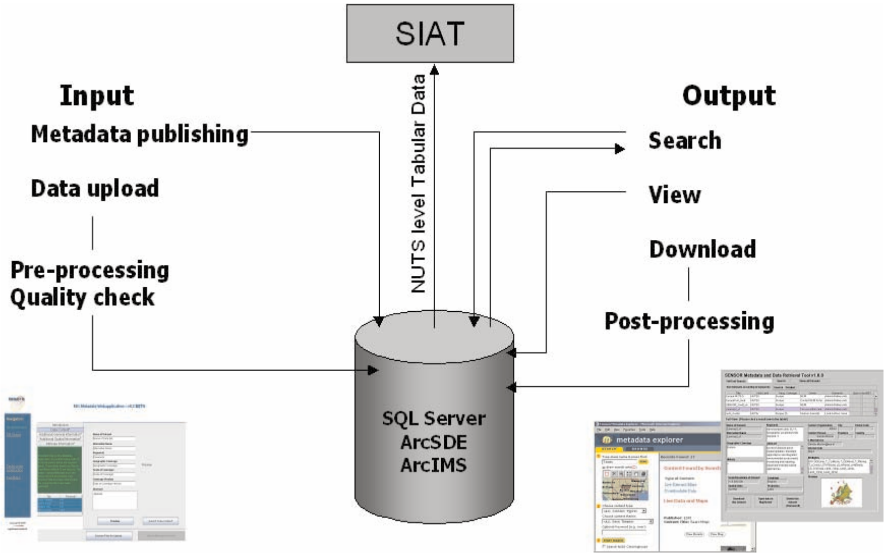

Fig. 5. Principles for SENSOR Data Management System

3.3 Output – The SENSOR Geoportal

The general entrance to the system is through the SENSOR GeoPortal. The Geography Network Explorer as well as the INSPIRE GeoPortal are both examples on how to use an Internet Map Server based Geoportal for searching, discovering and retrieval of data. The SENSOR GeoPortal is based on an Internet Map Server, and the main competitors among Internet Map Servers are ArcIMS from ESRI and MapServer, which is an Open Source implementation. MapServer is free of charge and an open concept, with unlimited possibilities for developing targeted implementations. This is obviously an advantage. However, the implementation effort can be a rather tough job, because we have to develop the whole end user application by ourselves, and this is certainly a disadvantage. ArcIMS is a rather expensive product, but comes with built-in applications for administration and authoring as well as end user applications. However, we still have the possibility to extend the standard applications – or even build our own application using Java. The choice between the two alternatives is at first sight not easy, but taking into account that the software environments of the end users are ESRI based it was decided to use ArcIMS.

The OGC WMS connector produces maps of geo-referenced data in image formats (PNG, GIF, JPEG) and creates a standard means for users to request maps on the Web and for servers to describe data holdings. The OGC WFS connector enables ArcIMS to provide Web feature services that adhere to the OpenGIS Web Feature Service Implementation Specification. The connector provides users with access to geographic (vector) data, supports query results, and implements interfaces for data manipulation operations on Geographic Mark-up Language (GML) features served from data stores that are accessible via the Internet. GML is an OpenGIS Implementation Specification designed to transport and store geographic information, and it is a encoding of Extensible Mark-up Language. The main development environments for the SENSOR Geoportal are Java and ArcXML, which is the protocol for communicating with the ArcIMS Spatial Server (ESRI, 2002).

3.4 Spatial Data Mining

The immense amount of geographically referenced data produced by developments in digital mapping, remote sensing, and the global diffusion of GIS emphasises the importance of developing *data driven* inductive approaches to geographical analysis and modelling to facilitate the creation of new knowledge and aid the processes of scientific discovery (Openshaw, 1999). Spatial data mining aims to uncover spatial patterns and relations.

The main difference between data mining in relational database systems and in spatial database systems is that attributes of the neighbours of some object of interest may have an influence on the object and therefore have to be considered as well (Ester et al. 2001). The explicit location and extension of spatial objects define implicit relations of spatial neighbourhood (such as topological, distance and direction relations), which are used by spatial data mining algorithms. Therefore, new techniques are required for effective and efficient data mining.

There are several major categories of data mining techniques (Ester et al., 1997):

- **Clustering** is the task of grouping objects into meaningful subclasses, so that members of a cluster are as similar as possible, whereas the members of different clusters differ as much as possible from each other. Thus clustering can be used to discover regions with low economic growth.
- **Characterisation** is the task to find a compact description for a selected subset of objects – e.g. to characterise certain target regions such as areas with a high percentage of unemployed. Spatial characterisation does not only consider the attributes of the target regions but also neighbouring regions and their properties.
- **Classification** refers to the task of discovering a set of classification rules that determine the class of any object form the values of its attributes.
- **Spatial trends** describe a regular change of non-spatial attributes when moving away from certain start objects. Global and local trends can be distinguished. To detect and explain such spatial trends, e.g. with respect to the economic power, is an important issue in geography.

A major challenge for this part of the SENSOR Data Management implementation is therefore to do research and development on effective methods for determining spatial and non-spatial relationships between datasets. The tools are based on recent advances in spatial data mining and knowledge discovery as described by Ester, Kriegel and Sander (2001) and facilitate *location prediction*, *spatial association*, *spatial clustering* and *spatial trend detection*.

4 Data policy

The data policy covers aspects of data access, ownership, licensing, and Intellectual Property Rights (IPR) on the data used within the framework of the SENSOR project. The SENSOR data policy follows the principles to be developed under the INSPIRE initiative (INSPIRE, 2002b). Currently, however, only a position paper on ‘Data Policy and Legal Issues exists, which lacks relevant details. As a consequence the SENSOR data policy has been developed as a consensus among the SENSOR partners, following the indications given in the INSPIRE position document. It might need revision when more detailed guidelines become available under the INSPIRE initiative.

Following these principles, it will be important that all data used and generated in the frame of SENSOR are well documented following strictly the SENSOR metadata profile (Table 2) and that the relevant search facilities are available. Furthermore, it is important that all data are available to the whole SENSOR community under clear conditions. Questions of data ownership, copyrights and conditions have now been clarified in order to encourage the disclosure and upload of data available as well as their widespread use within the SENSOR community.

4.1 Upload policy

All partners are encouraged to upload metadata on data of common interest and possibly to upload the data themselves. The uploading institution will retain the ownership of the data and will specify the conditions of use of the data. For any dataset to be uploaded, a copyright statement must be included in the metadata. By uploading the data, the data provider (owner) agrees that all SENSOR partners have free access to the data for their work within the SENSOR project. If not explicitly specified otherwise, all other uses will have to be authorised. It is strictly forbidden to deliver data to third parties outside the SENSOR project or to use the data for purposes outside the SENSOR project without the written consent of the data owner. Inquiries from third parties should be transferred to the data owner for clarification. All datasets must be accompanied by metadata, and the metadata will be freely available also for further (public) distribution. Data sets can be uploaded once the metadata are completely available and the data policy and copyright agreement has been accepted.

Table 2. The metadata list for SENSOR with associated ISO 19115-Standard codes

Metadata on metadata		ISO Code
• Point of contact		
• Name of contact organisation	*	8.376
• Name of contact person	*	8.375
• Address: City		8.378.389.382
• Address: Province, state		8.378.389.383
• Address: Postal code		8.378.389.384
• Address: Country		8.378.389.385
• Address: E-mail	*	8.378.389.386
• Address: web link	*	SENSOR specific

Data set identification

• Title of the data set	*	15.24.361
• Abstract	*	15.25
• Keywords	*	15.33.53
• Topic category	*	15.41
• Date of version	*	15.24.362.394

Reference system (SENSOR: information transferred via XML)

• Name of reference system	(*)	13.196.207
• Datum name	(*)	13.192.207
• Projection (Information via XML)		
• Name of projection	(*)	13.190.207
• Standard parallel	(*)	13.194.217
• Longitude of central meridian	(*)	13.194.218
• Latitude of projection origin	(*)	13.194.219
• False easting	(*)	13.194.220
• False northing	(*)	13.194.221
• False easting northing units	(*)	13.194.222
• Scale factor at equator	(*)	13.194.223
• Longitude of projection centre	(*)	13.194.224
• Latitude of projection centre	(*)	13.194.225

Distribution information

• Owner		
• Name of owner organisation	*	15.29.376

Other information

• Language within the data set	*	15.39
• Exchange format		
• Name of exchange format	*	15.32.285
• Scale	*	15.38.60.57
• Resolution (if raster data set)	SENSOR specific	
• Spatial Entities (NUTS-hierarchy)	SENSOR specific	
• Data type (vector / raster / tabular)	SENSOR specific	
• List of attributes	SENSOR specific	

(Attribute information via XML-file or XLS-table-header –parsing)

The "Data-type"- line above indicates, that our metadata profile is not only considering geo-spatial data but is also dealing with tabular data, which are non-spatial but referenced to spatial entities via identification code (ID).

4.2 Download policy

All SENSOR partners have full access to the metadata system, where they can search for data and information on the conditions of their use. Available datasets can be downloaded for use within the SENSOR project. Before downloading the data, the user agrees on the conditions of use of the data (data policy and copyright agreement).

4.3 SENSOR accepted Data formats

Data submitted to the Data Management System should follow certain standards. XML is emerging as the international standard for exchange of information, and you can easily import and export XML data in most modern GI software systems like ArcGIS. However due to the often huge size of geographic data sets, XML has had limited success in the GI Community. Instead native data formats from vendors like ESRI are used. In the SENSOR project, data should be exchanged in one of the following formats:

1) ESRI Shapefiles;
2) ESRI Personal Geodatabases;
3) Erdas Imagine or TIFF;
4) ESRI Coverages and Grids via Exchange File Format (E00);
5) XML / GML;
6) Tabular data (e.g., statistics for administrative regions).

These data need to be linked to a geographic entity via a common feature code – often a NUTS identification.

In principle, SENSOR data should comply with INSPIRE recommendations. This implies that data should be provided in a compliant reference and projection system, i.e. ETRS89 specifications (Annoni et al., 2003) and that grids should follow the INSPIRE grid specifications (JRC, 2003). This is very important in order to make these data readily available and useable for different applications. In case partners should have problems to convert the data, the data management team can try to help to solve the problem, provided that the data provider is able to give a detailed and accurate description of the projection system of the data. However, we underline that this should not be the rule and that in principle it remains the task of the different modules to provide data in the correct projection system.

5 Core data

The INSPIRE Working Group on Reference Data and Metadata encourages establishing a reference or core data set as an instrument to harmonise data from various sources. The recommendations from this group were: a) Geodetic reference data; b) Units of administration; c) Units of property rights (parcels, buildings); d) Addresses; e) Selected topographic themes (hydrography, transport, height); f) Orthoimagery; g) Geographical names.

During the further work with INSPIRE, the reference data set was changed a little bit – now also including European Grid in the so-called annex 1 data (COM, 2004). Within SENSOR we have chosen a geodetic reference system, administrative boundaries in form of NUTS, European Grid, CORINE Land cover, LANMAP and the European Digital Elevation model as our reference data set. By defining a SENSOR core data set we encourage partners to use for example the same NUTS map – although many different versions are available. Concerning the role as data harmonisation element, the datum, the projection, the NUTS administrative boundaries and the European Grid play the most important role. Those are described below.

5.1 NUTS

EuroStat established the Nomenclature of Territorial Units for Statistics (NUTS) more than 25 years ago in order to provide a single uniform breakdown of territorial units for the production of regional statistics for the European Union. The NUTS classification has been used since 1988 in Community legislation. But only in 2003, after 3 years of preparation, a Regulation of the European Parliament and of the Council of NUTS was adopted. From 1st May 2004, the regions in the 10 new Member States have been added to the NUTS.

The NUTS nomenclature is currently defined only for the 27 member states of the European Union. For additional countries comprising the European Economic Area (EEA) and also for Switzerland, a coding of the regions has been accomplished in a way, which resembles the NUTS. The NUTS map in SENSOR is based on SABE (Seamless Administrative Boundaries in Europe), which is an official product developed by EuroGeographics. The data behind SABE is the official administrative boundaries prepared by the national mapping agencies. The scale is generally 1:100,000. Aiming at a more equal size of the NUTS-3 polygons, within SENSOR a special version called NUTSx has been developed, where NUTS-3 is the basic map, but some countries, which have very small NUTS-3 entities - e.g. Germany - is represented by NUTS-2 (Renetzeder et al., 2008).

5.2 European Grid

The European grid should be used mainly for European purposes, but it can be useful also for national purposes. The datum to be used is ETRS89 as previously identified by INSPIRE. The geographical location of the grid points is based on the Lambert Azimuthal Equal Area coordinate reference system (ETRS-LAEA). The cartographic projection is centred on the point N 52°, E 10°. The coordinate system is metric. The square shape will appear when used in the defined projection, smaller or larger distortions will appear when re-projected to other projections.

Naming the individual cells can be done in several ways, but in SENSOR we have decided to use the so-called Direct Coordinate Coding System (DCCS), which concatenates the coordinates of Easting and Northing of a grid point. The length of the coordinates defines the precision of the grid. A grid with a precision of 1 m would require a maximum of 7 digits by each dimension. The resulting code would have 14 digits. A grid with a precision of 1 km would be defined by a code comprising 8 digits. Leading zeros are coded in order to preserve the precision information. Grid code identifies south-western corner of a cell.

5.3 CORINE Land cover

CORINE Land Cover (CLC) is a map of the European Environment Agency produced for the years 1990 and 2000. It provides comparable digital maps of land cover for each country for much of Europe (European Environment Agency, 1999, Bossard et al., 2000). The European land surface is classified using 44 classes of the 3-level CORINE nomenclature. CORINE Land Cover is produced mainly from satellite images, but aerial photos and near-ground imaging were also involved in the production. CORINE Land Cover in vector or raster formats is publicly available at no cost through the European Environment Agency web site.

5.4 LANMAP2

LANMAP2 is a Landscape Map at a scale of 1:2,000,000 covering the whole of Europe, from Iceland in the northwest to Azerbaijan in the south-east and from Gibraltar in the southwest to Novaya Zemlya in the north-east (Mücher et al., 2003; Mücher et al., 2006). Thus, LANMAP2 covers an area of approximately 11 million km^2. LANMAP2 is a hierarchical classification with four levels. The highest level (1) of the classification is determined by climate and has only eight classes. The second level is determined by climate and topography and has 31 classes. The third level, determined by climate, topography and parent material has 76 classes. In addition to this, the most detailed level (4) incorporates land cover and ends up with 350 landscape types.

6 Conclusion

The SENSOR Data Management System provides state-of-the-art core functionality for uploading data and metadata, storing data, searching and exploring data, selecting and downloading data. Use of off the shelf software complying with international standards like W3C, ISO TC/211 and the OGC are the implementation platform. When we talk about SENSOR Data Management we actually mean SENSOR Spatial Data Infrastructure dealing with all aspects of data management. Thus not only the technical aspects are included but also the economic and legal dimensions of data are addressed.

The first part of the Data Management System was already developed during summer 2005. This first component comprises the SENSOR Metadata Publishing system, and closely related to this is the data upload application, which still is under improvement. This data upload application could play an important role in establishing, at some level, data harmonisation and integrity.

The second part of the system was the implementation of the Data Warehouse with attached SENSOR GeoPortal for searching, exploring, selecting and downloading data. During this second phase, the connections between the Data Management system and SIAT have been established.

The third part of the system will deal with the development of tools for Spatial Data Mining and necessary pre- and post-processing tools. Data mining has the potential to equip users with extended analytical capabilities that can enable them to discover non-obvious relationships *between datasets*. By augmenting data discovery tools with spatial data mining, it is envisaged that users will discover related datasets that they would have otherwise overlooked. A major challenge for this final part of the SENSOR Data Management implementation is therefore to implement do research and development on effective methods for determining spatial and non-spatial relationships between datasets.

Generally speaking, during the process of developing the overall design of the SENSOR Data Management system, some "working" prototypes of different parts mentioned above have been developed. We see the main task for the nearest future in the bringing the various components together and establishing the integrated system.

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Part IV

European level indicator framework

An indicator framework for analysing sustainability impacts of land use change

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Abstract

Indicators can represent important sources of information for different stages in the policy-making process. Indicator frameworks are ways to organize and systematize indicators for making them consistent, transparent and end-user oriented. The paper initially describes the role that indicator frameworks may have in achieving policy relevance for indicators, ensuring that indicators correspond to the values, policies and targets of policy-makers. Next, the paper addresses different types of frameworks and exemplifies these with indicator frameworks that integrate environmental objectives into sectoral policies. The characteristics of frameworks for sustainability impact assessment and the development of an indicator framework for the SENSOR project are described. This includes concepts and models of sustainable development and indicators in Europe, and the criteria used for the construction of a SENSOR framework for indicator selection. The strengths and drawbacks of the framework are discussed.

Keywords

Sustainability impact assessment, indicators, indicator frameworks, end-user demands

1 Introduction

An indicator is, according to the European Environment Agency, 'an observed value representative of a phenomenon to study'. Indicators quantify information by aggregating different and multiple data, resulting in synthesized information that can be used to communicate complex phenomena in a simple way (EEA, 2005a).

Indicator frameworks are systems which provide a structure for indicator selection and development. Taking the questions and values of end-users as a starting point, indicator frameworks serve to ensure an end-user focus in indicator selection as well as coherence with regard to the purpose of the indicator sets, be it monitoring, policy analysis or another. While there has been extensive research focusing on the technical/rational aspects of indicator development, the role of indicator frameworks is poorly understood. This paper discusses the roles and potential of indicator frameworks, based on experience gained in developing an indicator framework for ex-ante sustainability impact assessment of land-use change for indicator selection and development in the SENSOR project. The paper firstly addresses the role and characteristics of indicator frameworks in general as tools to ensure consensus about issues and values attached to the policy area in questions. Then it goes on to describe frameworks specifically for sustainability impact assessment. This is followed by an illustrative example detailing the development of the SENSOR indicator framework, and a discussion of strengths and drawbacks of this framework.

2 The role and use of indicators in policy making

The development, monitoring and evaluation of policies are increasingly required to be based on evidence, and indicators are seen as a tool for this purpose. This was suggested in Agenda 21, the plan of action which resulted from the United Nations Conference on Environment and Development in Rio de Janeiro, 1992. The declaration described the role of indicators as follows:

> 'Indicators of sustainable development need to be developed to provide solid bases for decision-making at all levels and to contribute to a self-regulating sustainability of integrated environment and development systems'. (Agenda 21, chapter 40.4, UN 1993)

Aggregated indices in widespread use such as GDP (Gross Domestic Product) for national economies and HDI (Human Development Index) for measuring national development from a social perspective have long been in existence, while recent decades have witnessed an explosion in the number of indicator sets at all levels – especially in the realm of the environment – as a consequence of increased public awareness of environmental issues and their relationship to economic and social issues. Indicator sets for sustainable development assessment and monitoring are now commonplace in national policy settings.

Indicator sets are expected to support policy making by informing various phases in the policy cycle. These phases are policy identification, development, implementation and evaluation (Barkenbus 1998). De Ridder (2005) refers to a longer list of policy processes for which sustainability assessments could be relevant. Consequently, relevant indicator sets would include indicators for:

- Monitoring and assessment of conditions (identification/agenda setting)
- Strategic ex-ante impact assessment of policies (development)
- Assessment of performance in the relevant policy area (implementation)
- Policy analysis and evaluation (evaluation)

It has been argued that even though a vast number of indicators and indicator sets is available, the use and influence of indicators may still be weak (Rosenström and Kyllönen 2007, Gudmundsson 2003). This observation is due to that the instrumental, or direct, use of indicators by decision-makers is only one way of using indicators, and that the indicators may play a lesser role than would be expected from the many justifications stated at the time of indicator development.

Other uses are, according to Rosenström (2006), symbolic use (justification of wanted actions or decisions), process use (learning by people involved in the evaluation process) and imposed use (mandatory use of research). Indicators and indicator frameworks may, in a longer perspective, influence policies by changing the conceptual background of a policy, e.g. by framing how a problem is conceived. Hezri (2006) argues that indicators need to be 'policy-resonant', i.e. that they need to 'strike a chord' with intended audiences in order to be used.

De Ridder (2005) mentions two aspects which are important, if assessments should provide information of value to policy makers. The first is the level of consensus on the scientific knowledge about the issue at stake, and the other is the level of consensus on values associated with the issue at stake. This implies that an indicator which is accepted as having being built on high scientific validity may not have a correspondingly high influence on policy decisions if the values attached to the outcome are very different for different stakeholders.

This outlines an important role of indicator frameworks for decisions in policy making. A framework will ensure that existing and new indicators are placed in a specific context (OECD 1999), building on a conceptual model of the policy area in question. If the issues or themes covered by the framework are constructed such that they reflect the values and the objectives of the indicator end-users for the specific policy field, the likelihood that the indicators will be considered useful is likely to increase.

3 Types of indicator frameworks

An indicator framework serves the purpose of reflecting the relevant policy issues and objectives on which information is required as well as structuring the indicators to provide useful information on these issues and objectives. Thus, different types of frameworks exist which correspond to different phases of policy-making, and different policy areas and objectives. A well-known example of an indicator framework is the Pressure State Response (PSR) framework used by the OECD to structure its work on environmental indicators (OECD 2003). By organizing indicators into categories representing pressures, states and societal responses, the PSR model highlights the cause-effect relationships among the issues represented by the indicators, and structures the relationships between environmental, economic and other issues. The purpose of this framework has been to produce indicators that support the OECD policy analyses and evaluation work, as well as to contribute to harmonization of OECD member state initiatives (OECD 2003).

As mentioned in the introduction, research on the types and role of indicator frameworks is sparse. Gudmundsson (2003) has suggested typologies of indicator frameworks which may serve as an initial approach to distinguish between purposes. Gudmundsson first makes a distinction between the *conceptual framework* and *utilization framework* in relation to indicator sets.

The *conceptual framework* reflects the inner structure of the indicator system. Behind the conceptual framework lie societal or environmental concerns and a conceptual model of the system. This model describes the structural and functional components of the biophysical and societal systems and the linkages and feedback between them (Boyle 1998), and it is transformed into an indicator framework by identifying the end-user concerns, the cause-effect relationships and the relevant geographical scales and levels of detail for the indicators. It represents therefore a given world view, system boundaries and also 'blind spots', which are relevant aspects left out of the indicator framework (Gudmundsson 2003).

Such a conceptual model is found behind the cause-effect type of frameworks, e.g. the abovementioned PSR framework used by the OECD, and the extended version, DPSIR (D = driving force, P = pressure, S = state, I = impact and R = response) used by the European Environment Agency (OECD 2003, EEA 1999). These serve primarily as environmental indicator frameworks and are constructed as cause-effect frameworks, allowing trends in driving forces and pressures to be linked to state of the environment and impacts of change. These frameworks are used in various environmental assessment programs within the EEA (1999), OECD (2003) and several national projects (e.g. in Austria, South Africa, Australia). Different parts of the DPSIR framework may support different types of evaluation, e.g. efficiency of responses, eco-efficiency, risk assessment, dose-response relationships and impact assessments (Kristensen, 2004).

The *utilization framework* refers to the outer structure of the indicator sets defined by the presence of mechanisms to ensure the use of the information that indicators provide. Gudmundsson (2003) distinguishes between three types:

- *Information frameworks*, directed to a broad audience, and often without specified end users e.g. the sustainability indicator set provided by the United Nations (UN 2001)
- *Monitoring frameworks*, goal oriented, and directed at assessment of policy progress, e.g. TERM indicators, concerning environmental integration in transport, that build on the DPSIR conceptual framework (EEA, 2001)
- *Control frameworks,* aimed at clarifying where and how to act, and having stronger links to policy making. Control/audit bodies are end users

.These frameworks are built to inform specific policies or development goals. Within such a framework, issues to inform the different themes (e.g. water, nature conservation) or categories (pressures, states, etc.) are identified according to the purpose of the indicator set. An example of this is the integration of environmental objectives into sectoral policies; an EU policy aim embodied by the Cardiff process from 1998 (CEC, 1998). Within various sectors such as agriculture, energy and transport, indicator frameworks and indicators sets have been developed for monitoring this integration.

The IRENA (Indicator Reporting on the Integration of Environmental Concerns into Agriculture Policy) indicators build on the DPSIR framework as the conceptual framework as illustrated in Figure 1. In the IRENA framework the indicators have been structured within five themes identified as key for the integration strategy for the agricultural sector, i.e. water, agro-chemicals, land use and soil, climate change, as well as landscape and biodiversity (EEA, 2005b). These themes and their associated sub-issues largely shape the outer structure of the IRENA framework.

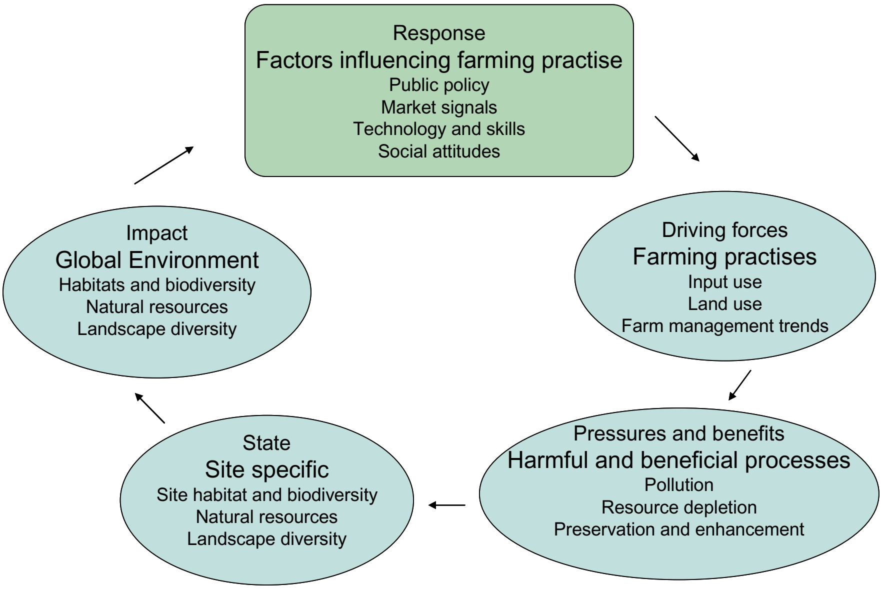

Fig. 1. The agriculture-environment DPSIR framework (CEC, 2000)

This example illustrates that indicator frameworks may reflect a conceptual framework as well as an utilisation framework, relating the indicators to end-user relevant key questions or themes.

4 Characteristics of indicator frameworks for Sustainability Impact Assessment

A number of frameworks for assessing sustainability exist. Many follow the three dimensional model of the overlapping spheres of economic, social and environmental development (e.g. Munasinghe 1992), but economic frameworks such as the extended national accounts and System of

Environmental and Economic Accounting (SEEA) as well as material flow frameworks have also been applied (OECD 1999). While single-value indicators have been developed by several international agencies, most national approaches rely on sets of indicators, often using the three dimensional approach, possibly combined with a causal chain model (e.g. the DSR) as a secondary organizational structure (OECD 2002). A few countries redefine the dimensions (e.g. France), while others focus on indicators qualifying 'transition', such as Sweden, where indicators are defined within the categories:

- efficiency
- contribution and equality
- adaptability
- values and resources for coming generations

The variability displayed above reflects that different values and sustainability criteria have influenced construction of the various indicator frameworks.

When developing an indicator framework for the assessment of impacts of actions (ex-post) or policies (ex-ante), focus is obviously on the output end of a causal chain analysis. The assessment of impacts, however, is not only limited to intended outputs of the actions/policy but also to broader societal concerns for sustainable development. Consequently, the conceptual framework for such an indicator system is not necessarily organized according to a causal chain structure, as it should primarily reflect the values and criteria attached to sustainability. It may, however, need such a causal structure, as indicators that relate adequately to the impacts are often difficult to establish. When this is the case, proxy indicators for impact may need to be selected from an earlier stage in the causal chain, such as pressure or state indicators.

5 An example: the indicator framework in the Sensor project

SENSOR is an integrated project aiming at producing a tool for ex-ante assessment of policies assuming to have an impact on European land use. The assessment should concern the impact of land-use changes on sustainability.

Production of a framework for indicator selection in SENSOR basically served two main goals, one focused on the internal project process and the other on the external SENSOR product, the tool for sustainability impact assessment (SIAT). The overarching internal goal was to ensure that indicator selection and production, taking place in several modules and work packages, would be harmonized and directed towards a common understanding of sustainability impacts across the project. Moreover, the different dimensions of sustainability were to be covered in a balanced way. The external goal was to ensure a demand-driven approach to indicator production, i.e. that the indicators produced were to be policy relevant and respond to the sustainability concerns of the end-users.

These concerns were mainly extracted from the European Union approach to impact assessment, as expressed in the EU impact assessment guidelines (CEC, 2006). These guidelines contain a screening list of impact issues and associated key questions, which reflect the three dimensions of sustainability in a balanced way. The issues reflected main policy areas in the EU, such as the Sustainable Development Strategy, combined with issues of good governance in accordance with the World Summit on Sustainable Development in Johannesburg (CEC, 2002a) and economic competition as emphasized in the Lisbon strategy (CEC, 2005).

Consequently, the end-user orientation for the SENSOR indicator framework was obtained by using a utilization framework in which the themes were based on the impact issues established by the EU impact assessment guidelines. In this way the framework enabled transparency in the indicator selection procedure and highlighted issues for which indicators could not be produced in the project. This allows the potential for users to assess these impacts by other means and methods.

Both the conceptual and the utilization framework were defined based on the EU IA guidelines. The inner structure comprised the three dimensions of sustainable development, i.e. economy, environment and society. The outer structure was defined in terms of the impact issues and associated key questions, which ensured that the specific policy under assessment would not contradict other main EU policies.

Subsequently the impact issues and questions became the outset for further development of the SENSOR framework, and were subsequently discussed in an internal consultation process, mainly based on considerations such as sensitivity towards the six sectors, baseline and policy scenarios, and causal links to land-use changes considered in SENSOR. While this first phase of the consultation pointed out those impact issues which were judged to be relevant for the SENSOR case, the second phase identified those for which indicators would be produced in SENSOR (supply-side considerations).

Table 2. The SENSOR indicator framework*)

SOCIAL	**ENVIRONMENTAL**	**ECONOMIC**
SOC1: Employment and labour markets	ENV1: Air quality	ECO1: Competitive-ness, trade and in-vestment flows
SOC3: Social inclusion and protection of particu-lar groups	ENV2: Water quality and resources	*ECO2: Competition in the internal market*
SOC4: Equality of treat-ment and opportunities, non-discrimination	ENV3: Soil quality and re-sources	ECO3: Operating costs and conduct of business
SOC6: Governance, par-ticipation, good admini-stration, access to jus-tice, media and ethics	ENV4: The climate	ECO4: Administrative costs on business
SOC7: Public health and safety	ENV5: Renewable or non-renewable ressources	ECO5: Property rights
SOC10: Tourism pres-sure	ENV7: Land use	ECO7: Consumers and households
SOC11: Landscape iden-tity	ENV8: Waste production / generation / recycling	ECO8: Specific re-gions or sectors
	ENV9: The likelihood or scale of environmental risks	*ECO9:Third countries and international rela-tions*
	ENV10: Mobility (trans-port modes) and the use of energy	ECO10: Public au-thorities
		ECO11: The macro-economic environment

*) The issues in italics are not expected to be produced in SENSOR.

The indicator framework, however, contains both phase one and phase two impact issues, ensuring transparency in relation to the products of SENSOR, and the possibility of complementing the SENSOR indicators with assessments based on other methods. The resulting SENSOR indica-tor framework includes 8 social issues, 10 environmental issues and 11 economic issues. A new social issue, landscape identity, was included, based on the argument that land-use changes had the potential to change this in a European context increasingly important aspect to a considerable degree. The SENSOR indicator framework is presented in Table 2. The impact issues in italics are those for which indicators will not be produced in SENSOR.

6 Conclusion

In a large project like SENSOR an indicator framework specifying which issues should be covered by the impact assessment tool developed is necessary. This ensures harmonization of the results from different stages in the project, and from different policy cases. A framework of impact issues moreover ensures a demand-driven approach, by directing modelling and assessment efforts towards end-user relevant issues. Finally, a framework ensures that the three dimensions of sustainability are considered, even if the model tool does not produce results for all issues, or even if results are unbalanced in terms of coverage of each of the dimensions.

As EU policy has a number of well-defined objectives for various policy areas, including sustainable development, policy coherence – or coordination of measures - is essential for ensuring that one policy does not contradict objectives in other policy areas. An indicator framework for sustainability impact assessment serves as a tool to ensure that broader societal objectives are not obstructed by a sectoral policy focussing on specific sectoral objectives.

The indicator framework developed for SENSOR has some immediate strengths and drawbacks. It aligns closely with the EU Impact Assessment Guidelines, and should be able to give answers to a relatively large number of those questions which are relevant in relation to impacts of policies affecting land use. Moreover, it ensures a balanced assessment in terms of dimensions of sustainability and transparency in terms of gaps in modelling capacity.

A drawback of the framework is that it may not wholly reflect sustainability values and criteria - mainly due to the lack of sustainability criteria behind the impact issues, which cover broader EU policy areas than the Sustainable Development Strategy (Tabbush et al., 2008). The impact issues are isolated in the three dimensions and do not include cross-cutting aspects. On the other hand, the framework and the indicators are developed as tools for sustainability impact assessment, and do not pretend to deliver the final assessment.

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Indicators for assessing the environmental impacts of land use change across Europe

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Abstract

Much progress has been made in understanding future trend development over the last years. Governments and international bodies are increasingly attempting to assess ex-ante the impact of their policy proposals. In the SENSOR project, environmental sustainability is assessed by answering a set of policy relevant questions likely to affect goods and services provided by land. The answer is complex and the assessment of future options is very sensitive to scale, how far ahead in time is being considered, and whether the assessment addresses local, regional or global concerns. The relationships between components of land use and the response of environmental indicators are not necessarily linear and assessing impacts at a European scale implies to use multi-scale sources of data of uneven quality across countries, which in turn creates constraints when interpreting the results at different spatial levels.

This chapter describes the methodology that was designed to undertake the environmental impact assessment in the SENSOR project. It presents the rationale behind the selection of indicators for environmental sustainability and addresses how environmental indicators can be derived from outputs of sectoral models, using two selected environmental indicators as an example. General issues connected to the modelling of environmental impact at pan-European level are discussed.

Keywords

Environmental indicators, DPSIR, impact issue, sectoral model, Land use, modelling

1 Introduction

Over the last years, much progress has been made in understanding future trend development. An increasing number of governments and international bodies are attempting to assess ex-ante the impact of their policy proposals. This chapter describes the methodology that was designed to undertake the environmental impact assessment in the SENSOR project. It presents the rationale behind the selection of indicators for environmental sustainability and addresses how environmental indicators can be derived from outputs of sectoral models using two selected environmental indicators as an example. General issues connected to the modelling of environmental impact at pan-European are discussed.

Prospective analyses of environmental impacts usually rely on the DPSIR framework as it assumes a chain of causal links starting with *Driving forces* (economic activities such as transport or agriculture) through *Pressures* (e.g. emissions of pollutants, land use change) that impinge upon the *States* of sensitive environmental receptors (such as soil pH or vegetation type). The changes in these states, i.e. the *Impacts* on the environment, such as increase in pH or species loss, eventually stimulate political or technological *Responses,* such as limits to air pollution, or the promotion of new farming systems (OECD, 1993). For scientists, DPSIR provides some conceptual support in problem exploration and a sound method for tackling integration. This chapter focuses on issues related to the assessment of the impacts of the environment.

Implementation of the DPSIR framework for prospective analyses of environmental impact has become widespread (EEA, 1999; Millennium Ecosystem Assessment, 2003), yet , environmental impacts of land use change have initially been tackled only in a qualitative manner as scenarios for future land use at large scale were lacking (Petit et al., 2001). This gap has been partly addressed in the recent years through various research projects ranging from the development of scenario narratives (Hoogeven and Ribeiro, 2007), the downscaling of global change scenarios (Rounsevell et al., 2006) and the design of rule-based land use change models driven by environmental and socio-economic factors (Verburg et al., 2006). SENSOR is an implementation of the DPSIR framework that includes its own internal land use change scenarios (Kuhlman et al., 2008), yet the main difference with the projects mentioned above is that it aims at assessing the impact of land use change on the environmental, social and economic pillars of sustainability.

The environmental issue at the heart of sustainable development relates to whether or not the ecosystem goods and services we need (such as food, water regulation, habitat provision, etc.) can be delivered at the required levels (Millennium Ecosystem Assessment, 2003). In the SENSOR project, environmental sustainability is assessed by answering a set of policy relevant questions likely to affect those goods and services, for example what will happen if it is decided at the EU level to introduce subsidies for the production of heat and electricity from biomass (Kuhlman et al., 2008), and what are the consequences of this decision on land use, nutrient flows and finally on water quality? The answer is complex and the assessment of future options is very sensitive to scale, how far ahead in time is being considered, and whether the assessment addresses local, regional or global concerns. The relationships between components of land use and the response of environmental indicators are not necessarily linear and modelling impacts at a European scale implies to use multi-scale sources of data of uneven quality across countries. This in turn creates constraints when interpreting the results at different spatial levels. The SENSOR project addresses some of these issues by assessing sustainability across a range of scales up to the year 2025.

2 Indicating the environmental impacts of changing land use

For the DPSIR framework to be implemented, a set of indicators describing the relevant problem areas of the environment has to be made available for each part of DPSIR (EEA, 1999). These indicators ought to capture the essence of the issue and should have a clear and accepted normative interpretation, be robust and statistically validated and respond to policy interventions. As such, they supply consistent information on issues so that policy-makers can value their seriousness and therefore set priorities for policy development. Indicators simplify a complex reality and, if chosen correctly, are as such a great tool for communication between science, politics and stakeholders in general (Fassio et al., 2005; Hagan and Whitman, 2006) and represent a powerful tool to raise public awareness on environmental issues (OECD, 1998), therefore strengthening public support for policy measures. Over the last decade, many international organisations (i.e. European Commission, European Environment Agency, OECD), have put much emphasis into the development of indicators which monitor the effects of pressures on the environment. Examples of indicators focussing on the environmental impact of land use change can be found in the ELISA project 'Agri-environmental indicators for sustainable agriculture in Europe' (Wascher, 2000), the IRENA indicator project (EEA, 2006) and in the EEA core set of indicators (EEA, 2005a) and updated OECD environmental indicators (OECD, 2007).

In the SENSOR project, the choice of relevant indicators within SENSOR was first guided by the EC Impact Assessment Guidelines (CEC, 2005) which lists 12 environmental impact issues which cover most components of our environment (air, soil, water, land, biodiversity) or risk associated to those such as climate impacts, pollution or human and animal health issues. This framework is further elaborated in Frederiksen and Kristensen (2008).

- ENV1: Air quality
- ENV2: Water quality and resources
- ENV3: Soil quality and resources
- ENV4: Climate
- ENV5: Renewable and non-renewable resources
- ENV6: Biodiversity, flora, fauna, landscapes
- ENV7: Land use
- ENV8: Waste production/generation or recycling
- ENV9: Environmental risks
- ENV10: Mobility (modal split) and use of energy
- ENV11: Environmental consequences of business activities[1]
- ENV12: Animal health and food safety[2]

For each impact issue, the Environmental Impact Assessment Guidelines propose a set of specific questions which should be addressed. For example, the question asked on ENV1 Air quality is: Does the option have an effect on emissions of acidifying, eutrophying, photochemical or harm-

[1] This impact issue was discarded in SENSOR as it was mostly already covered under parallel impact issues (impact on air, soil, water, climate and landscape of farming, forestry and tourism)

[2] This impact issue was not addressed as we were unable to assess the issue with the list of potential indicators that could be modelled in SENSOR.

ful air pollutants that might affect human health, damage crops or buildings or lead to deterioration in the environment (polluted soil or rivers etc.)? In SENSOR, we therefore attempted to answer these sets of question by means of indicators.

The choice of relevant indicators was further dictated by the DPSIR approach adopted in SENSOR; in essence, there must be a logical (quantitative or qualitative) relationship between the indicator and the results of the policy modelling carried out within the project. It requires that the changes in land use and management can be related to the changes in one or more indicators in a causal way that is appropriate for the scale of the assessment. For our purposes, the key scale is that we should be able to assess changes at the NUTSx, scale for the year 2025, on the basis of pan-European functions and data.

In order to assess whether all the proposed indicators met all the criteria mentioned above, fact sheets were developed to answer the three questions ('what, why and how'):

- What is the indicator supposed to measure, what quantity does it represent?
- Why is the indicator thought to be relevant to the concepts of sustainability and multifunctional land use? Is it found in other indicator sets? Do EU policies have anything to say on it?
- How can it be modelled? What data are available to show the current values of the indicator and the past trends therein, and at what spatial level is the indicator available? How can the sectoral models used in SENSOR be made to forecast changes in the indicator values as a consequence of policy changes? What are the issues related to model quality and uncertainty?

The resulting set of indicators is presented in Table 1. No indicator could be identified for ENV10 'Mobility and use of energy' that met the criteria above.

Table 1. List of indicators per impact issue that fulfil the SENSOR criteria

Impact Issues	SENSOR indicators
ENV1 Air quality	ENV1.2 Ammonia NH_3 emission ENV2.2 Nitrogen oxides NO_X emission
ENV2 Water quality and resources	ENV2.1 Nitrogen (N) and phosphorus (P) surplus ENV2.2 Water abstraction rate
ENV3 Soil quality and resources	ENV3.1 Soil water erosion ENV3.2 Soil sealing
ENV4 Climate change	ENV4.1 Carbon stocks and sequestration ENV4.2 Methane and nitrous oxide emission ENV4.3 CO_2 emission
ENV5 Renewable and non-renewable resources	ENV5.1 Biomass potential
ENV6 Biodiversity, landscapes	ENV6.1 Proportion of terrestrial habitats at risk from eutrophication ENV6.2 Trends in Farmland birds ENV6.3 Deadwood ENV6.4 High Nature Value Farmland ENV6.5 Spatial Cohesion ENV6.6 Pesticide use
ENV7 Land use	ENV 7.1 Land use cover
ENV8 Waste management	ENV 8.1 Generation of municipal waste by tourists
ENV9 Environmental risks	ENV 9.1 Forest fire risk

3 Modelling the environmental impact of land use changes

For the reasons mentioned in the previous section, it is crucial that the models should maximise the expression of the relationship between the results of the policy modelling carried out within the SENSOR framework and its potential environmental impact, i.e. the indicator under focus.

In term of modelling, much emphasis has been put into linking existing models (Jansson et al., 2008). The core model is the NEMESIS model, which includes models for urban area (SICK), tourism (B&B) and transport infrastructure (TIM). Specific linkages were developed between this core model and the CLUE-S land allocation model to derive areas of land affected by policy scenarios (Verburg et al., 2008). In addition to NEMESIS and CLUE-S, two important models outputs were used in modelling environmental impacts of policy scenarios.

The agricultural sector model CAPRI (Britz, 2005) is linked to NEMESIS and CLUE-s and provides a number of outputs related to agricultural land use, agricultural production, nutrient flows and surplus in the agricultural system.

The forestry sector model EFISCEN (Schelhaas et al., 2007) responds to policy scenarios through wood demand (from NEMESIS), changes in forest area (from CLUE-s) and changes in management strategies. It provides outputs related to the structure of the forest (area, volume, increment, etc.) and forest carbon stocks in biomass and soil.

Table 2 lists the models linked to each environmental indicator and the spatial resolution at which each environmental indicator is being modelled.

Table 2. Environmental indicators of land use change and their links to sectoral models developed in SENSOR and their spatial resolution

Indicators	**Link to SENSOR sectoral models**	**Spatial resolution**
ENV1.1 NH_3 emission	NEMESIS, CAPRI	NUTS-x
ENV1.2 NO_X emission	NEMESIS, CAPRI	NUTS-x
ENV2.1 N and P surplus	CAPRI	NUTS-x
ENV2.2 Water abstraction rate	CLUE-s, EFISCEN	NUTS-x
ENV3.1 Soil water erosion	CAPRI, CLUE-s, EFISCEN	NUTS-x
ENV3.2 Soil sealing	CLUE-s	NUTS-x
ENV4.1 Carbon sequestration	EFISCEN, CLUE-s	NUTS-x
ENV4.2 Methane and nitrous oxide emission	CAPRI	NUTS-x
ENV4.3 CO_2 emission	EFISCEN, CLUE-s, NEMESIS	NUTS-x
ENV5.1 Biomass potential	CAPRI, EFISCEN	NUTS-x
ENV6.1 % of terrestrial habitats at risk from eutrophication	NEMESIS, CAPRI, CLUE-s	NUTS-x
ENV6.2 Trends in Farmland birds	CAPRI	National
ENV6.3 Deadwood	EFISCEN	NUTS-x
ENV6.4 High Nature Value Farmland	CAPRI, CLUE-s	NUTS-x
ENV6.5 Spatial Cohesion	CLUE-s	NUTS-x
ENV6.6 Pesticide use	CAPRI	NUTS-x
ENV 7.1 Land use cover	CLUE-s	NUTS-x
ENV 8.1 Generation of municipal waste by tourists	CAPRI	NUTS-x
ENV 9.1 Forest fire risk	EFISCEN, CLUE-s	NUTS-x

Once the links between outputs from the policy modelling and the environmental indicators have been established, attempts had to be made to formalise the relationship. The relationship between land cover and management and the environmental indicator can take almost any form, from a statistically tested quantitative model, validated at the appropriate scale to a qualitative rule-based model using expert knowledge. Some response functions fell in between the two categories and used expert-opinion to build linkages in the conceptual model and used data to implement the conceptual model.

Issues of data quality and uncertainties were explicitly described along with the methodology for modelling each indicator. One common difficulty identified has been the use of data sources that were available at different levels of resolution; firstly, CLUE-S provides information at 1km resolution, while NEMESIS typically provides information at the national (NUTS0) level. Secondly, several indicators required the use of external datasets available at other resolutions, e.g. the EMEP data on Atmospheric Nitrogen deposition used to calculate ENV6.1 'Proportion of habitats at risk from eutrophication' available in a 50km grid or with inherent limitations e.g. ENV6.4 'High Nature Value farmland' is derived from CORINE Land cover which means it has a minimum mappable unit of 25 ha. In some cases, it has not been possible to disaggregate some of the data sources at the NUTSx level e.g. ENV6.2 'Trends in farmland birds' required data on current and past species distribution and this data was only available at the national level.

Two examples of indicators that are developed within SENSOR are presented below and represent different approaches. The first example shows how an indicator can be derived from outputs from sectoral models, and the second example illustrates how an indicator can directly be included in a sectoral model.

3.1 Example 1: ENV 2.1 Effects of changes in N surplus on water quality

Definition and relevance

The indicator ENV 2.1 'Effects of changes in N surplus on water quality' evaluates the risk of N leaching to ground or surface water as well as surface runoff. N surplus is relevant because a persistent surplus may indicate potential environmental problems, eventually resulting in pollution of drinking water and/or eutrophication of surface waters. N surplus represents the balance between nitrogen inputs (fertilisers, nitrogen fixation by legumes, and deposition) minus nitrogen removed with harvest and is currently the best available measure for nutrient leaching risk. National nutrient balances may provide a first overall indication of the potential risks for the water quality. They can however mask important regional differences in the gross nutrient balance that determine actual nitrogen leaching risk at regional or local levels. Indeed, there are a number of regions in Europe where pig livestock units have increased by more than 25% during the recent years that are likely to be regional 'hotspots' for high gross nitrogen balances (EEA, 2005b). In the SENSOR context, i.e. an assessment of the impact of land use changes, this indicator plays a central role. Policies which affect land use in the agricultural sector (e.g. regulations related to livestock and fertiliser use) have a direct impact on N surplus, and consequently a potential impact on water quality.

Methodology

The diffuse load through leaching or surface runoff from agriculture is estimated to be responsible for up to 80% of the total nutrient load to rivers and catchments (EEA, 2005c). Therefore, our methodology specifically relied on outputs from the agricultural sector models. The agricultural sector model CAPRI calculates N surplus (kg N/ha) as described by Meudt and Britz (1997), and integrates the effects of the different types of farming systems that can occur within regions (Britz, 2005). Although N surplus is correlated with N leaching and run-off to some extent (Børgesen et al., 2001; Halberg et al., 2005; Schröder et al., 2005), the potential risk for water quality is highly dependent on the actual soil characteristics and distance to water bodies. Therefore, the assessment also relied on three additional factors. The risk assessment considered Nitrate Vulnerable Zones designated in each member country as these zones are defined as sensitive to nitrate leaching and require extra precaution regarding N surplus (Figure 1). Additionally, it also considered key agro-ecological conditions, such as soil type, which is essential to provide estimates of the potential nutrient leaching and runoff, because sandy soils have a higher risk than clayey soils. Finally, the risk of runoff to surface waters is considered to be highest in areas with high proportion of open lakes, rivers, wetlands or other water bodies and therefore we considered the proportion of area covered by these land cover types in the regions that were assessed.

In terms of modelling, we used some simple qualitative rules and risks factors associated with different states of the 4 variables cited above. The deviation between two given land use change scenarios was expressed as ΔN, the change in N surplus. We then assigned risks scores for the different values of ΔN i.e. a ΔN greater than 1% (significant increase in N surplus) was scored 200; a score of 100 was attributed to changes that were minor ($-1\,\% < \Delta N < 1\%$); any other value of ΔN was assigned a score of zero. Areas located within NVZ were given an additional risk score of 10.

Regions in which at least 50% of the area was covered with sandy soils were given an additional risk score of 1. Finally, regions with more than 2% of their area covered with water bodies (threshold based on the distribution of values within Europe and expert knowledge) were given an additional risk score of 1.

The overall risk assessment was derived by adding up the various risk scores described above at each NUTS level. Resulting values that were below 100 indicated a decrease in N surplus and therefore a potential improvement of the water quality. Values below 200 indicate that there might be a minor increase in N surplus, and consequently a minor risk for the NUTS with indicator values 110, 111 or 112, which means that they are situated in NVZ. The highest risk will be at indicator value 212, which indicate increased N surplus, nitrate vulnerable zone, more than 2% of the area covered by water bodies, and more than 50% of the area is sandy soil For simplicity, scores can be aggregated into 4 main categories of risk as described in Table 3.The category no risk includes situation where the risk associated to N surplus has actually decreased between two scenarios i.e. scores varying between 0 and 12.

Table 3: Definition of risk categories for the impact of N surplus on water quality.

Risk category	**Description**	**Scores**
High risk	$\Delta N > 1\%$ AND NVZ = 1	210, 211, 212
Medium risk	$\Delta N > 1\%$ AND NVZ = 0	200, 201, 202
Low risk	$-1\% < \Delta N < 1\%$ AND NVZ = 1	110, 111, 112
No risk	ELSE	All other scores

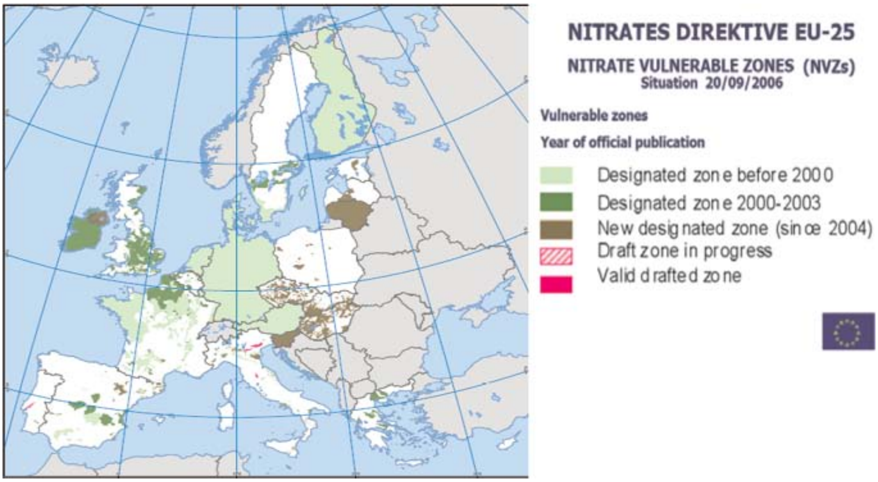

Fig. 1. Nitrate Vulnerable Zones (NVZs) in EU 25 (Source: JRC, EC 2006)

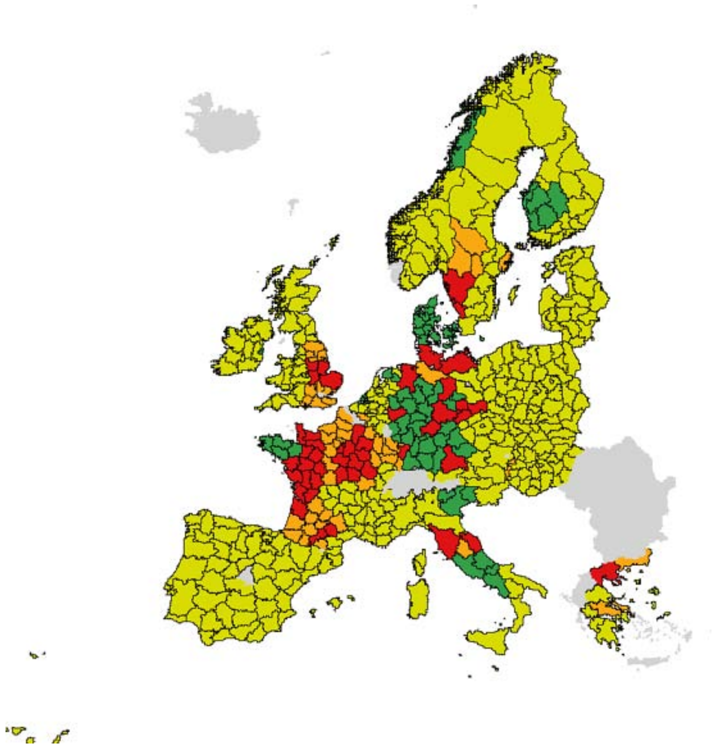

Fig. 2. Distribution of risk classes resulting from an example where a policy case is compared to 'business as usual'. See text for details.

Implementation

Within SENSOR, we compared a standard scenario (‘business as usual‘) to a test scenario with 50% reduction in set-aside land area. The combination of the spatial distribution of risks factors enables to derive the spatial distribution of the risk for water quality (Fig. 2). Red areas are those with increased N surplus after set-aside areas were reduced by 50%, which in combination with high proportion of nitrate vulnerable zones, high proportion of sandy soils, and high proportion of surface water bodies, is resulting in the highest potential risk for the water quality. Green areas are those where the 50% reduction in set-aside land area caused a decrease in N surplus as compared to ‘business as usual’, and therefore a potential reduction in N leaching and improvement of the water quality. Finally, yellow areas are those where the policy case did not cause any significant change in N surplus compared to the standard scenario, and therefore no impact on N leaching and water quality.

3.2 Example 2: ENV6. 3 Deadwood in European forests

Definition and relevance

ENV6.3 Deadwood describes all non-living woody material not contained in the litter. It includes standing deadwood, deadwood lying on the surface and stumps. It is an indicator that captures many elements of naturalness of forests in Europe (Dudley & Vallauri, 2004); its quantity and quality is crucial to the survival of many endangered specialist species (Siitonen, 2001) and the indicator is one of the main indicators for forest biodiversity at the political level (MCPFE, 2003).

It is widely recognised that intensive forest management has led to a significant reduction of the amount of deadwood in forests as well as the types of deadwood with in particular a reduction in the presence of large diameter trees in advanced stages of decay (Siitonen, 2001). ENV6.3 Deadwood is well suited to the SENSOR project as it is an indicator that is sensitive to changes in policy through changes in forest management regimes and intensity.

Methodology

To estimate the indicator within the SENSOR framework, impacts of policies on ENV6.3 Deadwood are directly projected by the forestry sector model EFISCEN which describes the state of the forest by matrices in which area is distributed over age and volume classes (Schelhaas et al., 2007 and Jansson et al., 2008). Transitions of area between cells within a matrix represent different processes such as growth, ageing and harvest. A specific module was developed to project natural mortality and deadwood dynamics to assess the impact of policies on the amount of deadwood in forests.

The estimation of ENV6.3 Deadwood required different steps, notably the estimation of forest increment and mortality functions. Forest growth in EFISCEN is described by Net Annual Increment (NAI), the volume increment of the growing stock excluding mortality (death of trees through natural tree death, diseases, insect attacks, fire, wind-throw or other physical damage) (UNECE-FAO, 2000). As deadwood is the result of mortality, a correction had to be made to the growth function in EFISCEN. This correction converts net annual increment to gross annual increment (GAI). The difference between NAI and GAI is the growth of trees before they died, which is included in GAI. Mortality itself has been included as a mortality ratio that is calculated as a percentage of the growing stock. The mortality ratio determines how much area should be transferred one volume class down to obtain the required reduction in growing stock. Mortality occurs in EFISCEN in forests that are not thinned or felled in the same time-step. For all countries in SENSOR either the mortality ratio is obtained from national forest inventories, or the correction factor to convert net increment to gross increment is derived from UNECE-FAO (2000). If either the mortality ratio or the correction factor was obtained, then the other could be calculated through the balance of gross increment, net increment and mortality.

Once a tree dies, it enters the standing deadwood pool and it leaves this pool by falling down or by removal during management. The amount of standing deadwood can thus be calculated from the initial amount of standing deadwood, the input of deadwood from mortality and deadwood leaving the standing deadwood pool by falling down or removal during management;

$$SDW_t = SDW_{t-1} + m_t - (r_t + k) \cdot SDW_{t-1} \tag{1}$$

where SDW_t is the mass or volume of standing deadwood at time t, r_t the deadwood removal rate for time t, m_t the mortality projected by EFISCEN at time t and k the fall rate constant that describes a negative exponential fall rate (Storaunet and Rolstad, 2004). The standing deadwood pool is initialised as equilibrium between the input of litter, the fall down rate and the deadwood removal rate of the first time-step. No loss in volume or mass due to decomposition is assumed while standing (Krankina and Harmon, 1995; but see Yatskov et al., 2003; Mäkinen et al., 2006).

Fallen dead trees and harvest residues are sources of input to the lying deadwood pool. A fallen tree decomposes and volume and mass of lying logs decrease. Volume and mass do not decrease at an equal rate; mass reduces generally faster than does volume (Krankina & Harmon, 1995; Krankina et al., 1999; Mäkinen et al., 2006). Few studies focused on losses of volume, but more did on mass loss. Fractionation and decomposition of logs is therefore modelled as a reduction of mass; volume of lying deadwood is not projected by EFISCEN. Fractionation and decomposition is modelled by the dynamic soil carbon model YASSO that is linked to EFISCEN for each region and species. A detailed description of YASSO is given by Liski et al. (2005). The amount of lying deadwood at time t is estimated by LDW_t as the balance between input of deadwood, determined by the fall rate k and the mass of standing deadwood SDW_t, and the release of carbon to the atmosphere through fractionation and decomposition of lying deadwood.

All EFISCEN results are disaggregated to NUTS-x level by distributing the results over the NUTS-x regions that are located within an EFISCEN region, using forest cover (as projected by CLUE) as a weight. The final indicator value for each NUTS-x region is then calculated by summing up $\mathrm{SDW_t}$ and $\mathrm{LDW_t}$.

Implementation

As an illustration, we compared outputs for the indicator under two scenarios. The first scenario assumed a baseline demand for wood (Kangas and Baudin, 2003; Schelhaas et al., 2006; FAOSTAT, 2007), while in the second scenario the demand for wood was increased by (10-20% in the period 2011-2025, in relation to increasing bio-energy production. In addition, the second scenario assumed that 75% of harvest residues were removed from the forest. The impact of increased management intensity on deadwood in European forests in 2025 is shown in Figure 3.

An increase of wood and residue removal for bio-energy production across Europe is projected to result in a decrease of the amount of deadwood. Increasing wood demand leads to increasing forest management intensity and this reduces the tree mortality. Consequently less standing and lying deadwood is formed and present in forests. The amount of lying deadwood is further reduced through a decreasing input of stem tops and stumps after harvesting. This example suggests that bio-energy policies through a decrease of deadwood can negatively affect forest biodiversity.

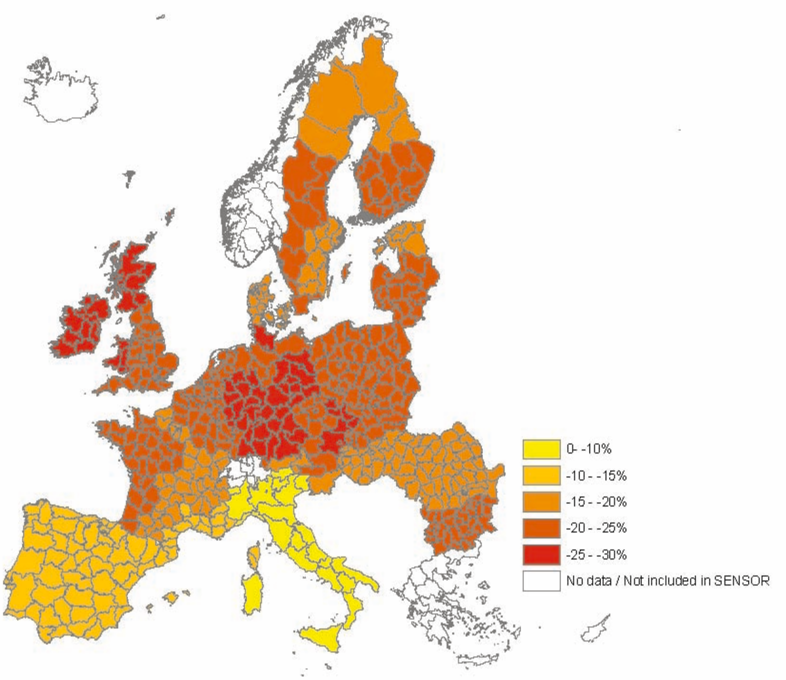

Fig. 3. Impact (% change of mass) of increasing wood demand and harvest residue removal for bio-energy production on dead wood in European forests in 2025.

4 Conclusion

In the past, most of the relationships between land use and its environmental impacts have been assessed at local scales, whereas assessments and published models for research at the European scale were scarce. However, this situation is improving rapidly and pan-European assessment of the environmental impacts of land use change are emerging, that move from the collation of expert knowledge derived from local scales (Petit et al. 2001) to the development of formal pan-European models of particular causes of environmental change (Veldkamp and Verburg, 2004; Alcamo et al., 2005; Metzger et al., 2006; Petit and Elbersen, 2006).

The SENSOR project is delivering a substantial contribution to pan-European research on environmental impacts of land use change. Almost 20 spatially explicit indicator models for EU-27 are being produced that summarise the relationship between land use and environmental indicators that are highly policy relevant. The conceptual modelling of the relationship between components of land use and the response of environmental indicators should be done as accurate as possible. But the challenges of pan European cross-sectoral modelling are multiple and lie notably in the use of multi-scale sources of data of uneven quality across individual countries. In the case of ENV6.3 Deadwood a model sensitivity analysis showed that the mortality level projected by EFISCEN depended largely on the mortality ratio specified in the model input (Schelhaas et al., 2007). Given the limited data availability on (tree) mortality and deadwood dynamics at the national level for EU-27, there is inherently important uncertainty in the estimation of the indicator at least for some countries. In the case of ENV 2.1, which assesses risks to water quality as a result of N surplus, it is the relationship between N surplus and N leaching that is the key factor determining the degree of uncertainty. N surplus is estimated in CAPRI as amounts of N applied minus N removed from the soil surface, whereas the impact on water quality is depending on the amount of N actually reaching the ground water bodies, i.e., amount of N leached below the rooting zone. N leaching is highly dependent on the type of soil in the rooting zone and may vary from 0.1 in clay soils to about 1 in sandy soils (Schröder et al., 2005). One main reason for this variation is that the denitrification, i.e., the microbial process converting nitrate into gaseous products, is more important in clay soil than in sandy soils. Therefore, we used a qualitative approach with N surplus as the primary indicator, and state variables, such as soil types, as additional information in order to narrow down the uncertainty in assessing the risk for water quality.

The calculation of indicators is based on datasets generated by sectoral models and from external datasets. These sectoral models have been developed in many cases for different purposes, they are based on different underlying datasets and they vary in the assumptions made in each model (Jansson et al., chapter 8). Consequently, this causes associated methodological issues such as spatial (dis)aggregation. Some of these problems (and solutions) have been described in Paracchini et al. (2008), but it is crucial to keep in mind the constraints and limitations resulting from these issues when interpreting results. E.g. the results from CAPRI are originally calculated at the NUTS-2 level and results from EFISCEN for variable administrative boundaries (generally NUTS-0 to NUTS-2). Results from both models are disaggregated, providing input for indicator calculations at the NUTS-x level. Yet, the disaggregation procedure does not increase the spatial resolution of the models.

Linkages between models are also crucial. For example, in the case of ENV 6.3 Dead wood, sensitivity analyses showed that management intensity had a great impact on the projected mortality level (Schelhaas et al., 2007). Management intensity is largely determined by wood demand and therefore strongly depends on the link between NEMESIS and EFISCEN (Jansson et al., 2008)

On the other hand, the integration of different land use sectors in the impact assessment is a major achievement of SENSOR. While some policy relevant indicators can be derived directly from one sectoral model, it is necessary for many other environmental indicators to use outputs of different sectoral models. Such indicators could perhaps also be assessed at the pan-European scale with more global models, but the approach chosen in SENSOR enables us to apply the best available models for the important land use sectors.

Once the models are implemented and provide interpreted estimates for indicator values under various scenarios, the question remains how much the change in selected indicators matters. Issues associated with this evaluation will be developed in the next chapters of this book.

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Reflections on Social and Economic Indicators for Land Use Change

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Abstract

The context of sustainability as embodied in SENSOR, using the 'triple bottom line' concept, is briefly identified, and consequent frameworks and criteria for identifying indicators are discussed. These theoretical and practical criteria set significant constraints on the possible indicators to be used. The indicators are discussed in a summary form, and lessons are drawn. Reflections on the indicators and their use conclude the chapter.

Keywords

Social indicators, economic indicators, sustainability, land-use changes, modelling, indicator selection

1 Introduction

Several chapters in this book allude to the role of indicators in sustainability impact assessment: Tabbush *et al.* (2008) discuss the concept of sustainability and the Triple Bottom Line; Tscherning *et al.* (2008) examine how these concepts are used in the EU and elsewhere; Helming *et al.* (2008) discuss the application of these concepts in SENSOR, including the role of indicators in impact assessment; Sieber *et al.* (2008) show how to operationalise indicators; and Frederiksen and Kristensen (2008) propose a framework for the identification of indicators. The present chapter and the following one (Petit *et al.*, 2008) describe the indicators actually used in SENSOR, i.e. how the thoughts developed in preceding chapters have been implemented into the indicators that form the basis of impact assessment.

The chapter is structured into five sections. Firstly, we reflect briefly on ideas of sustainability as they are incorporated in SENSOR. Secondly, we discuss indicator frameworks in the context of the project's requirements for social and economic indicators, and thirdly we review criteria for indicator selection. Fourthly, we describe the social and economic indicators selected for this project. Finally, we reflect briefly on the usefulness and limitations of the selected indicators. Our aim is to explain the development of social and economic indicators in SENSOR, and to reflect on some of the issues involved.

1.1 SENSOR and the concept of sustainability

The concept of the triple bottom line, borrowed from the language of corporate social responsibility (Elkington, 1994), has become popular in the policy discourse around sustainability. As such, it has found its way into the methodology of impact assessment practised by the European Commission, exemplified in the Impact Assessment Guidelines (CEC, 2005). In this concept, sustainability is split into environmental, social, and economic dimensions. The latter generally refers to monetary income and expenditure. Alternatively, social sustainability contains those aspects of welfare that cannot be expressed directly in monetary terms – or if they can they refer to the distribution of wealth rather than its aggregate size. The role of the Impact Assessment Guidelines is discussed below.

We note that the triple bottom line is basically about 'strong' sustainability – wherein substitution is not assumed to easily occur between the various dimensions of sustainability (Pearce and Atkinson, 1992). 'Weak' sustainability – wherein such substitution is assumed – is also used in SENSOR, namely in the Externality Accounting Framework (Ortiz et al., 2007). Its aim is to measure indirect (external) effects of policy changes in money terms, for instance the health effect is measured in increased or decreased costs of health care, and pollution is measured as the putative cost of clean-up.

1.2 The Role of Indicators in SENSOR

The goal of SENSOR is to assist EU policy-makers in impact assessment of policies affecting land use, the basis for which is laid out in the Impact Assessment Guidelines of the European Commission (Kristensen et al., 2006). Thus, using this document as the basis for indicator selection in SENSOR has the advantages of retaining consistency and of using a framework with which policy-makers will be familiar.

Impact assessment may be seen as studying a process in which a policy acts as a driver and an indicator measures the effect of the policy. Causal relationships connect the drivers with the indicators. In SENSOR this is conceptualised following the DPSIR framework, which has become popular in policy-oriented environmental research in recent years (Frederiksen and Kristensen, 2008). In the SENSOR approach, one can say that the drivers are partly policies, and partly contained in the baseline scenarios (Kuhlman, chapter 6 in this volume); the pressure factor is represented by the land use change resulting from the action of policies and other drivers; the state factor is represented by intermediate model outcomes; and, finally, the impact can be assessed through indicators.

As Frederiksen and Kristensen (2008) also state: “the focus is necessarily on the outcome end of the DPSIR causal chain”. This should be a guiding principle for the identification of indicators. In practice, though, this may not always be possible, and in such cases elements of state or pressure may have to be measured; but this should at least be recognised, and indicators related to impact should be preferred whenever possible.

It is also necessary to balance a desire to have a comprehensive list of indicators against the potential for double counting. For instance, polluted water may cause mortality among fish, which can be of concern because of reduced biodiversity but also because of lower catches by fishermen and unemployment. Furthermore, it may cause health problems for humans as well as reduce our enjoyment of beautiful scenery. Finally, certain measures may be taken to clean the water, which will cost money. If all of these elements are used as indicators, there is a risk of overstating the problem.

Finally, a point to which the discussion will return is that it may sometimes be difficult to distinguish between *environmental, social and economic* indicators.

1.3 Criteria for identifying indicators

The European Commission’s classification of ‘impacts’ in its Impact Assessment Guidelines (CEC, 2005), does not include explicit indicators.

Having established that where possible, *impact* indicators are being sought, suitability criteria should be applied for their selection. Seven criteria are proposed:

- They must represent politically relevant aspects of sustainability; SENSOR is dealing with applied research, so it is important that the client or stakeholders participate in the selection of indicators.
- They must be scientifically sound in that they are valid measures of sustainability dimensions. Often, the particular aspect the stakeholder is interested in cannot be measured directly or comprehensively; the burden of proof is then on the researcher to find a variable that can be considered a reasonable indicator for that aspect.
- They must be practicable in that they can actually be modelled; ideally, indicators should be identified first, after which models are sought or created that can forecast those indicators. In practice SENSOR uses several models from different sources, designed for different purposes (Jansson et al., 2008).
- They must be responsive to the policies being evaluated in that they are likely to be influenced by those policies. For instance, governance may have been established as being important to the stakeholders, and a variable may have been identified that can be modelled and that is a good indicator for it; but if the policy being evaluated has no effect on it, it will not be a useful indicator.
- The indicators should be measurable in a sufficiently comparable way across member states. Full comparability is an ideal that cannot normally be attained; however the aim should be to reach an acceptable standard of comparability (Atkinson et al., 2002). A requirement of SENSOR is also that the indicators are intended for measurement and forecasting at the regional level, where possible.
- The indicators should be timely and susceptible to revision. Revision of data is important where advances are made in understanding and where there are changes in policy concerns (Atkinson et al., 2002).
- Finally, there should be as few indicators as possible, bearing in mind the need to capture the social and economic impacts of policy-induced land use change. The more indicators there are, the more opaque the process of impact assessment will become.

Atkinson et al (2002) propose a number of principles, both for ‘single indicators’ and for a ‘portfolio of indicators’, in the context of indicators relating to social exclusion in the EU. A ‘single indicator’ principle of interest here is that an indicator should have “a clear and accepted normative dimension” (Atkinson et al., 2002). In SENSOR the philosophy is normative in the sense that the Sustainable Impact Assessment Tool (SIAT) will use model output to show possible future scenarios, and a direct (sustainable) effect on policy is the expected potential outcome of the tool's use by policy-makers. The context in which SENSOR's 'single indicators' are used is therefore in accord with normative principles.

The portfolio should be "balanced across different dimensions" (Atkinson et al, 2002) – in the context of social inclusion that Atkinson et al are dealing with, they mean different dimensions of social exclusion. This idea can be applied to SENSOR indicators, where it would mean that ideally there is a 'balanced' range of *social* indicators and also a balanced range of *economic* indicators – and, of course, a balanced range of *environmental* indicators. Thus, the overall portfolio of SENSOR indicators should be 'balanced' too.

Two comments may be made on this point. Firstly, each team responsible for each group of indicators (social, economic, and environmental) has itself attempted to obtain balance through a range of indicators that *taken together* reflect appropriate dimensions of sustainability – as viewed by those experts, and also through a process of peer critique among the SENSOR project team as a whole. Secondly, the use of Land Use Functions in SENSOR (Pérez-Soba *et al.* 2008) in effect produces portfolios of indicators grouped (again, through a rigorous process of expert peer review) according to the Land Use Functions system. This enhances utility for policy-makers, and also meets the scientific principle of a 'balanced portfolio', or grouping, of indicators.

Some issues arise in SENSOR from applying these seven general criteria, summarized as follows:

1. The effect of the criteria in combination is to create a rather 'small gate' for indicators to pass through. Indicators were selected in an iterative process that involved consultation with end users (policy makers), literature and data searches, and expert brainstorming, both within different teams involved in SENSOR, and between the teams, at plenary meetings, and through e-communication. Compromises between different views naturally had to be made in some cases, through consensus.
2. There was considerable discussion among the teams in SENSOR about overlaps – and possible 'double counting' – between (some) social and economic indicators. The clearest example is perhaps employment, which can be viewed as a social indicator because it has to do with fulfilling one's potential and with welfare. But employment can also be regarded as an economic indicator, because it is routinely dealt with by economists, and because it is a major determinant of in-

comes. There is a case for regarding social and economic indicators together, as *welfare* indicators: these could conceptualise welfare in (moral philosophy) terms such as happiness, freedom from harm, etc – these being viewed (philosophically) as 'goods'. The social and economic indicators then assess shortfalls in the provision of these goods, as they are manifested through land use changes and associated activities.

3. Since SENSOR aims to assist policy-makers in assessing the impacts of policies on sustainable land use, it is necessary to be able to use the SIAT tool to forecast expected outcomes of policy decisions in the future. Thus, future values of indicators have to be modelled, using a chain of models as mentioned above, and as described in detail in Jansson *et al.* (2008): the list of available indicators (and the way they are measured) depends either directly on model output, or indirectly on indicators that can be calculated from model output. For instance, employment is generated directly by NEMESIS, but the visual attractiveness of landscapes has to be modelled on the basis of both land use change and the permanent characteristics of landscapes.
4. The ability to define and estimate certain indicators from the social perspective and the meaning of these is highly dependent upon how the reference scenarios are defined and the model chain used in SENSOR to estimate the effects of the policy cases. This is due, in the first instance, to the fact that a number of the key factors that influence the social indicators are assumed to not be influenced by the policy cases. See Table 1 below for a summary of the key assumptions of the baseline scenarios, which will remain fixed as exogenous inputs in the policy cases. For example, the demographic structure – the total population including age and gender structure – in each region[1] for each baseline scenario is an exogenous input into the models, i.e. it is pre-determined. As such, by assumption, there is no impact of any policy on demographic issues, such as actual net migration. It may make sense, however, to talk about potential pressures on migration. Similarly, combining the fixed assumptions for demography with fixed assumptions for labour force participation implies that available labour is also unaffected by the policy cases. Thus, changes in an indicator such as unemployment, which is a ratio of available employment to available labour, will only occur if there

[1] Here and elsewhere in this paper, regions refer to sub-national entities. These vary between indicators, depending on the capacity of models to provide spatial detail depending upon the model and indicator, so the generic term is used throughout this chapter.

is a change in the former. This is not the case for such factors as employment and economic growth in Europe. At the same time, even for these factors, a further complication is that many of the social indicators focus on distributional issues. For example, the gender pay gap depends on knowing how wages evolve separately for males and females; similar issues arise for indicators that focus on age groups, sectors, or regions.

The descriptions of the specific indicators provided in the next sections specify where the above concerns limit the ability to provide certain indicators, either at all or at the levels of aggregation that might be desirable.

Table 1. Key Exogenous Inputs defining the Baseline Scenarios

Unaffected by Policy Cases
Demography within Europe: including total population and age/gender structure by region
Demand for goods from Europe originating from the rest of the world
Price of petroleum on the world market
Aspects of the following may be affected by Policy Cases
Labour force participation within Europe: by age, gender, and region
Expenditure on research and development within Europe: by investment sector and country
Policies
Institutions
Cultural change

2 Social and economic indicators used in SENSOR – descriptions and observations

2.1 Social Indicators

2.1.1 Introduction

The Impact Assessment Guidelines of the European Commission (EC, 2005) list nine social impact issues. These are given as SOC1-SOC9 in Table 3. Based upon the framework and criteria discussed earlier in this chapter and in Frederiksen and Kristensen (2008), specific indicators were identified to be included in the SIAT. Unfortunately, the limitations posed by the models and the definition of the policy scenarios has meant that not all of the impact issues are represented in the set of social indicators, even some of those that might have been of interest to policymakers. Specifically, no indicators are being provided related to SOC2, SOC5, and SOC6.

In the process, however, two additional impact issues were found to be of interest – tourism pressure and landscape identity. Following the same nomenclature, these are listed as SOC10 and SOC 11 in Table 2.

Table 2. Impact issues for the social dimension of sustainability and associated indicators

Code	Title	Indicators
SOC1	Employment & labour markets	Total Unemployment and Employment by Sector
SOC2	Standards & rights related to job quality	0
SOC3	Social inclusion & protection of particular groups	Unemployment and Employment by Sector broken down by age and gender; Regional variations in income and employment
SOC4	Equality of treatment and non-discrimination	0
SOC5	Privacy & family life	0
SOC6	Governance & participation	0
SOC7	Public health & safety	Exposure to Air Pollution, Water Pollution, and Forest Fire Risk
SOC8	Crime, terrorism & security	Self-sufficiency in food.
SOC9	Social services	Migration Pressure
SOC10	Tourism pressure	Tourism Intensity
SOC11	Landscape identity	Visual Attractivity and Continuity of Appreciated Landscape Heritage

The remainder of this section briefly describes each of the social indicators being implemented in the SIAT. Each indicator is described and the level of spatial, sectoral and other resolution is noted. An indication is also made as to which of the impact issues the indicator is primarily associated.

2.1.2 Employment and Unemployment

The guidelines for SOC1, SOC3, and SOC4 address different aspects of the labour market, not just overall employment, but also consequences for particular professions, groups of workers, and groups within society. The indicators described here focus on a few of these aspects, notably overall levels of employment and unemployment and, as far as possible, how these differ between sectors, genders, and different age categories.

The demographic and macroeconomic modelling in SENSOR provides information on both labour supply and demand. The former are available broken down by age and gender, jointly[2]; the latter are not, but they are broken down by sector. Fortunately, the EU-KLEMS database[3] does provide some historical data indicating shares of employment by age and gender, separately[4], for sectors at the national level for most of the countries covered by SENSOR. Using these data and making the, admittedly simplistic, assumption that the information provided by EU-KLEMS applies uniformly at the sub-national scale and is constant over time; it is then possible to estimate the following at the regional level:

- Employment by sector broken down by gender and separately broken down by age
- Unemployment and unemployment rates broken down by gender and separately broken down by age[5]

These can also be aggregated to both the level of nations and the EU.

2.1.3 Regional Variations in Income and Employment

The guidelines for SOC3 and SOC4 pay particular attention to how different groups in society might be differentially affected by a policy. To some extent, these are addressed by the indicators on employment and unemployment. It would also be useful to consider other factors, such as income. Unfortunately, whereas it is possible within SENSOR to distinguish impacts on employment and unemployment by gender and age, at least to some extent, this is not possible for income. It is possible, however, to provide some indication how impacts on income differ by sector and region. Since the former, i.e. the difference by sector, is addressed in part by one of the economic indicators, the latter is focused on here. Using the data provided by the indicators on employment, a similar indicator of how employment rates differ by region can also be provided. Together, these can also be interpreted to provide an indication of cohesion between and within regions. As will be described below, these results serve a further purpose in that they can act as drivers for migration.

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[2] That is, specific data is available on the supply of females and males for each age category.

[3] See EU KLEMS Database, March 2007, http://www.euklems.net. The age categories are 15-29, 30-49, and 50+.

[4] That is, whereas the data indicate the share of employment by gender for each sector and the share of employment by age category for each sector, it does not provide data on the share of employment for a specific gender for a specific age category.

[5] Since the labour force is not broken down by sector, sectoral unemployment rates would not make sense.

The estimation of indicators related to regional variations in employment rate follows directly once the regional estimates of employment are calculated. With respect to income, an additional step is required. In addition to employment by sector, NEMESIS provides results for total compensation to employees by sector at regional level. Dividing the latter by the former yields average compensation per employee, this can be taken as a proxy for average income. While this could be done at a sectoral level for each region, in actual practice there will not be a difference within a sector across regions in the same country. Thus, the estimates for income will only be robust in the aggregate, i.e. for the region as a whole.

In both cases, at the regional level, these indicators can be expressed as the deviation from the mean at a higher level of aggregation, e.g. nations or the EU. At these more aggregate levels, it makes more sense to consider the variability among smaller entities, e.g. regions, so this is how the indicator will be presented.

2.1.4 Exposure to Air Pollution, Water Pollution, and Forest Fire Risk

The indicators of environmental impacts being considered in SENSOR are described in Petit et al. (2008). Among these are emissions of air pollutants – ammonia and nitrogen oxides, water pollutants – nitrogen and phosphorus, and forest fire risk.

These are being provided at the regional level and will indicate if the air and water quality is 'improvement over the baseline', 'no change from baseline', or 'decline from the baseline', where the baseline is the level in the associated baseline scenario. A similar approach is being used to present the indicator for forest fire risk.

In addition to being environmental impacts, these can also be considered to have social impacts, notably under issue SOC7 – Public health & safety. Of course, the degree to which this is the case is related not only to the environmental changes, but also to the level of exposure. For the individual regions, all that can be done is to note whether the population is exposed to an improvement, no change, or decline in air quality, water quality, or forest fire risk; as such, they are somewhat redundant in view of the environmental indicators. At national and EU levels, however, the sum of the population in the underlying regions falling into each category will be calculated. This can then be divided by the total population to provide an estimate of the percentage of population exposed to improvements, no change, or declines in air quality, water quality, or forest fire risk.

2.1.5 Self-Sufficiency Index for Food

A straightforward reading of the guidelines for SOC8 – Crime, terrorism & security – could imply that this is an issue that lies outside the interest of SENSOR. A more expansive interpretation of the concept of security, however, could include the notions of food and energy security, both of which are on the political agenda. Self-sufficiency, an aspect of security, is the ability to supply one's needs for a commodity (i.e. food) from one's own resources. Thus, in SENSOR, an indicator related to food self-sufficiency will be included.

The CAPRI model provides estimates of food self-sufficiency for both human and total consumption directly for a number of agricultural products, as well as for calories, fat, and protein as aggregates. The results for the total consumption of the latter are used, as food self-sufficiency is less a matter of specific foodstuffs than these aggregates. The data are provided at national level, which implies that this indicator can be provided only at this scale and that of the EU. This is not seen as a significant problem, though; reporting on self-sufficiency at the regional level is not common.

2.1.6 Tourism Pressure

Tourism as a spatial phenomenon involves the temporary stay by millions of people outside their region of residence. This causes a wide variety of both positive and negative impacts on the host regions widely addressed in the tourism literature for many years (e.g. Butler, 1975; Doxey, 1975; Murphy, 1985; Boissevain, 1996; Pearce et al, 1996). Impacts from tourism vary to some extent by the types of tourism, the infrastructure of the host regions, planning, and regulations etc. But generally, the impacts tend to increase with the number of tourists.

There are various potential measures of tourism intensity. Among these are arrivals, overnight stays, and tourism bed spaces. For present purposes, the latter is seen as the best option, as it expresses of the maximum number of tourists staying overnight at peak season in any region. This quantity must be related to the absorption capacity of the receiving region. Two different indicators have been constructed to express tourism pressure: in the first one, called social pressure, the peak number of tourists is compared to the size of the local population; in the second, called recreational pressure, it is compared to the available area of forest and nature.

2.1.7 Visual Attractivity and Continuity of Appreciated Landscape Heritage

Visual attractivity refers to the scenic value of the landscape and environment that is perceived and appreciated by people, where landscape is understood as defined in the European Landscape Convention: "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors" (European Landscape Convention, 2000). "Change of visual attractivity" shows the visual effect of land use changes. It is measured by edge density index as the edges of different land cover types are the physical manifestation of the land use. Edge density is calculated from the CLUE model outputs (2000-2025) and the change rate represents the loss or gain of visible linear structures in the landscape. The edges of different land uses and the related land cover make landscape visually more understandable, and also more attractive. Different types of edges have different functions in landscape scenery. A forest – pasture edge has more scenic value than an arable land – permanent crop edge. According to the literature of environmental psychology, the most valued landscape types have many wooded and non-wooded vegetation edges e.g. savannah type landscapes. (Wohlmeyer, 2003). Thus visual attractivity is only based on the density of visually significant edge types. These are the edges between the areas covered by wooded and non wooded vegetation, water, built up and bare surfaces. The indicator will specify whether the land-use related visual attractivity is increasing, decreasing, or remains the same.

Continuity of appreciated landscape heritage is an outcome of the preservation of biological and cultural diversity; it refers to natural and cultural heritage of an area, where the cultural part especially means artefacts, monuments, knowledge, and know-how of land use techniques, related to an area-specific land-use structure. (Van Eetvelde and Antrop, 2004, Nassauer, 1995) All these characteristic elements in a landscape give the identity, the unique sense of place. But not all character is positive in terms of environmental quality and sustainability. Monotonous, ecologically and aesthetically degraded landscapes may be regarded as not worthy of preservation. Landscapes can be distinguished according to their appreciation. The level of appreciation, defined by designations and tourists' attendance in an area, can be considered as a rather precise indication of whether the identity should be maintained or not. At the regional level, the World Database on Protected Areas and the EUROSTAT Database on tourism have been used to represent the present state of appreciation, and the CLUE-model outputs (2000-2025) provide estimates of land use change. Combining these two provides an indicator of the continuity of appreciated landscape heritage.

2.1.8 Pressures for Migration

Migration is the permanent or semi-permanent change of residence by an individual or group of people. It is usually considered at the national level, i.e. net migration is the total number of arrivals of foreigners and returning nationals minus departures of foreigners and nationals. Arrivals and departures of short duration, e.g. for tourism or business purposes, are excluded (OECD, 2006). This indicator, however, will apply to a finer spatial scale, i.e. it will indicate whether or not a policy would be expected to affect significantly the level of migration at the regional level compared with the baseline scenario. Since population and therefore migration levels are fixed by the reference scenarios, this indicator will not affect actual migration, but will give an indication of migration pressures. In SENSOR, this pressure is being used as a proxy for impact issue SOC9 – Social Services.

A number of different variables may influence migration at the regional level. Among those being considered are:

- Income;
- Other labour market conditions; and
- Non-economic attractiveness, e.g. visual attractivity and appreciated landscape heritage

It is not surprising that several of the variables are linked to other social and economic indicators. Others may be added if they appear to be important. Using historic data, the relationships between these variables and net migration are being analysed in order to determine trigger levels for migration. These will specify, for example, how much difference in regional GDP per head is needed to have a significant impact on net migration.

Once the variables with the best explanatory value are determined and thresholds are established, the indicator can be implemented. It is unlikely that the analysis of the historic data will produce results that are robust enough to provide quantitative estimates of the amount by which net migration would be expected to change. Thus, it is expected that the indicator will be qualitative, taking the form of a trichotomy: (+) significant increase, (-) significant decrease, or (=) no significant change.

2.2 Economic Indicators

2.2.1 Introduction

The Impact Assessment Guidelines of the European Commission (2005) list 11 issues of economic impact; they are listed in Table 3 below. Under each of these, the Guidelines ask several questions that ought to be answered by an indicator system. In the design of the SENSOR indicator list, each of these questions has been considered as to:

- whether any of the policies in the SENSOR policy cases is likely to affect it;
- whether the models are capable of predicting that effect.

Initially, a total of 24 indicators were identified, covering all of the 11 issues listed in the Guidelines. After considerable discussion within the SENSOR consortium, this was reduced to 10[6], covering 9 out of the 11 issues. They are listed in Table 3.

Table 3. Impact issues for the economic dimension of sustainability and associated indicators

Code	Title	Indicators
ECO1	Competitiveness	Net flow of traded goods per sector
ECO2	Internal markets	0
ECO3	Business operating costs	Labour cost; Energy cost
ECO4	Administrative costs	Administrative costs (qualitative)
ECO5	Property rights	Property rights (qualitative)
ECO6	Innovation & research	Labour productivity
ECO7	Consumers & households	Inflation rate
ECO8	Specific regions & sectors	Value added per sector
ECO9	International relations	0
ECO10	Public authorities	Share of public expenditure in GDP
ECO11	Macro-economy	GDP

2.2.2 Gross domestic product (ECO11)

This is actually the most directly relevant and easy-to-model economic indicator (not counting employment, which is here considered a social indi-

[6] The counting depends on whether or not one counts sectoral indicators individually; if so, there are actually 18.

cator). Costs and benefits of public policies (in terms of money) will ultimately be expressed in an increase or decrease of gross domestic product (GDP). Even though GDP has considerable drawbacks as a measure of human welfare (in that it does not include environmentally and socially deleterious effects of economic growth; that it disregards unpaid work and subsistence production; and that distribution of wealth is as important as its aggregate), it is still considered an important measure of the level of economic activity, and no impact assessment is complete without it.

It is generated in SENSOR by the macroeconomic model NEMESIS, and it can be disaggregated to the regional level by means of knowledge rules based on regional economic structure and past growth trends.

2.2.3 Value added per sector (ECO8)

Value added is basically the same as GDP: it is the total output of a sector minus the raw materials and intermediate goods spent in its production. One might argue that this indicator duplicates the previous one, since the latter is simply a component of the former. However, since SENSOR deals with specific sectors, it makes sense to make impacts on these sectors visible separately. The sectoral models adopted and adapted in SENSOR, as well as some developed specifically for this project enable the projection of these impacts also at the regional level.

This is relatively straightforward for the agriculture sector, and the NEMESIS model was modified in order to separate it from forestry and fisheries. In forestry, the problem is the shortage of economic data from which to make projections about the future. For the energy sector, value added is projected only at the national level, which is considered the most relevant. Tourism is not a sector in the economic sense; rather, some economic activities (such as transportation) take place partly on behalf of tourists. The sector which is most closely related to tourism is lodging & catering, so it can be used as a proxy for tourism expenditure. Regional projections are made on the basis of the number of overnight stays. The next sector in SENSOR is transport, but here it is only the infrastructure which is considered, not value added in the transport sector. Nature conservation is a very important activity in terms of land use, but not as a source of income. In other words, the indicator is calculated for agriculture, forestry and tourism at the regional level, and for energy at the national level.

2.2.4 Administrative costs (ECO4)

The implementation of new regulations often increases administrative costs on businesses. This is a matter of concern to the European Commission, which has set a target on reducing the administrative burdens of existing regulations, by 25% by 2012. It is expected that this reform will increase GDP by 1.5% – a sum of some €150 billion. Thus, the justification of this measure is that it will lead to economic growth.

The SENSOR models cannot actually predict changes in this indicator, so any increase in administrative costs will not be reflected in a lower score on GDP. We can establish causal relationships between it and the drivers, but these cannot be quantified – all that can be said is whether a particular policy is likely to have an impact on administrative costs. This will depend on the policy instrument. Fiscal measures to encourage certain behaviour will inevitably affect administrative costs. Decreasing subsidies will often not reduce administrative costs, which means these costs may actually increase as a proportion of the total impact. Thus, reducing overall market support without abolishing any of it will not reduce administrative costs; but abolishing support for a particular crop will.

The indicator is implemented by means of a table listing all policy variables, and indicating which changes in their settings would lead to changes in the level of administrative costs.

2.2.5 Labour productivity (ECO6)

This indicator was built because of a desire to show the direct result of innovations. One of the drivers in the SENSOR model system is the amount of money spent on research and development (R&D), by the private sector as well as from public funds. The relationship between R&D expenditure and increase in labour productivity is modelled in the macroeconomic model NEMESIS. There are, of course, many other factors which influence labour productivity, such as the education system, cultural factors, the level of investment, the protection of intellectual property, and the way new knowledge is converted into innovations. However, R&D is one fairly important factor and relatively easy to quantify.

One drawback of this indicator is that it duplicates gross domestic product. It is not really an impact indicator, but an intermediate one representing one of the determinants of GDP.

2.2.6 Labour cost (ECO3)

The indicator for labour cost, defined as the total expenditure on labour in the sectors agriculture, forestry and lodging & catering,[7] was built in response to the issue of business operating costs raised in the Impact Assessment Guidelines. It presents the same problem as the previous indicator, in that it is a component of GDP or, more precisely, of value added per sector.

The cost of labour is made up of two variables, namely price (wages) and quantity (employment). The *wage rate* depends mainly on labour productivity, which differs between baseline scenarios (with a high-growth scenario implying higher wages). Policy scenarios will generally have little influence on the overall wage rate, because the sectors with which SENSOR is concerned make up only a small proportion of total employment. However, there is one policy case which examines a fairly dramatic increase in research & development; this will lead to higher labour productivity – and hence higher wages. The quantity of employment per sector is one of the social indicators.

2.2.7 Energy cost (ECO3)

This indicator is very similar to the previous one: it is derived from the same issue in the Impact Assessment Guidelines (EC, 2005), it has the same relevance to sustainability, and it is also made up of (a) price and (b) quantity. The former is largely determined by the oil price, which in SENSOR is exogenous. However, European policies (for instance, related to greenhouse gas emissions or to renewable energy) can influence the price of energy on the domestic market and this can be modelled.

The quantity of energy consumption (measured as gross inland consumption) is determined by two factors, namely GDP and energy intensity, i.e. the amount of energy consumed per unit of GDP. This latter quantity has been in gradual decrease for many years. Figure 1 below shows the causal links determining both price and quantity of energy.

[7] Labour cost in the energy sector was excluded here, because it is a relatively unimportant component of total operating cost.

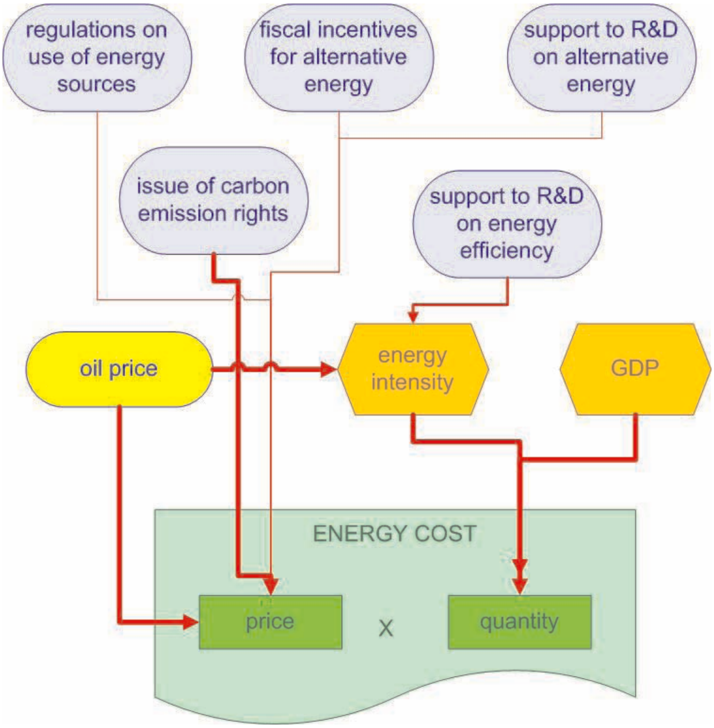

Fig. 1. Determinants of energy cost

2.2.8 Net flow of traded goods per sector (ECO1)

This indicator is defined as exports minus imports of goods and services for each of those sectors that can be modelled: agriculture, forestry, lodging and catering (as a proxy for tourism) and energy. For tourism, it is calculated on the basis of expenditure per overnight stay and the numbers of tourists, the latter being an output from the tourism sector model B&B. The other data can be generated directly by the macroeconomic model NEMESIS.

It is important to distinguish between exports to and imports from countries within the EU on the one hand and the rest of the world on the other hand. Both are important: member countries are concerned about their balance of payments, but the EU also functions as a single market. Adding up all imports and exports for all EU member states does not yield the overall trading position.

The interpretation of this indicator (which was intended to measure the competitiveness of the EU vis-à-vis the rest of the world) is difficult. What does it matter, for instance, if there is a negative net flow of goods in the agriculture sector? As an example, initial projections of what would happen if direct income support to farmers and exports subsidies were abolished show a dramatic decrease in agricultural production, which surely also implies a decrease in agricultural exports; however, total net exports increase significantly according to the models. In any case, if net flows of traded goods per sector are relevant to sustainability, they will affect GDP – which is also present as an indicator.

2.2.9 Public expenditure (ECO10)

Many of the policies to be assessed in SENSOR will have an impact on government revenue or expenditure. The model NEMESIS generates projections for public budgets per member state. These budgets have well-known effects on both aggregate GDP and its distribution over different population groups (Becker, 1985; Samuelson, 1958). Briefly, the higher the share of total GDP occupied by public expenditure, the lower the economic growth – at least as expressed by GDP. The exception is public expenditure of an investment character (such as infrastructure, education or R&D), which can have a positive impact on GDP. The distribution effect of public expenditure depends on the taxation system (whether it is, on balance, progressive, or retrogressive) and on the type of subsidies (whether they are biased more towards low-income groups or high-income ones). However, all these effects are pressures rather than impacts, and as such are measured by other indicators.

2.2.10 Inflation rate (ECO7)

Like the previous indicator, inflation can influence both economic growth and the distribution of income among different groups. Similarly, it is also a standard output of the model NEMESIS. It differs in that the policies assessed in SENSOR are unlikely to have a significant effect on inflation. There will be some effects: for instance, reduction of farm support would reduce food prices; and some energy policies would increase the price of energy. But these effects are likely to be marginal with regard to the overall price level. The relevance of inflation for sustainability rests mainly on its impact on income distribution. Therefore, it can be useful if there is no direct measure of income distribution in the indicator set. However, its interpretation is not straightforward: one cannot simply say that inflation is good for the rich and bad for the poor. Rather, it tends to benefit those with fixed-interest debts (including companies) and those who are able to negotiate their incomes (companies and wage-earners) and penalise those with fixed incomes and money assets (such as banks, people with savings accounts and pensioners).

2.2.11 Property rights (ECO5)

The Impact Assessment Guidelines contain a question about whether property rights are affected by a proposed policy or programme. The difficulty with this issue is to identify a quantity that measures it. Since such an index factor was not found, the indicator was made a qualitative one, analogous to the treatment of administrative costs. For the policies evaluated in the SENSOR system, the main issue is land use rights, which are affected by policies determining what one can or cannot do with the land.

As an impact issue, it is listed under the economic pillar, which indicates that property rights are here seen as a factor in determining GDP – the better property rights are protected, the higher the incentive to invest. However, property rights may also be considered a social issue, because the enjoyment of property is often a value in itself, and indeed enshrined as such in both the European Convention on Human Rights and the UN Declaration of Human Rights of 1948.

3 Conclusion

The identification, selection and operationalisation of indicators for social and economic impacts of land use change, as required in SENSOR, is a challenge. It seems intuitively clear that changes in land use have potentially far-reaching implications for social and economic well-being; given the large-scale changes in land use taking place in the EU, it is important to try to 'capture' at least some dimensions of the social and economic implications.

This must be done in a scientifically-based process that uses clear criteria derived from best practice, to select indicators that will be responsive to policy scenarios and changes envisaged by policy-makers, so as to assist them in decision-making about policies that will affect land use and sustainability. The precise ways in which indicators are linked to the functionality of land use changes also have to be identified and traced out, so that the relationship between the SENSOR model chain output and the indicators themselves can be expressed – quantitatively or qualitatively, unambiguously, and transparently – so that the end-user can readily understand the nature of the impacts being signalled.

The indicators explained here generally fulfil these requirements, although some of the economic indicators are redundant. They cannot, of course, capture every dimension of the impact of land use change on society and economy – on well-being – but they provide in themselves robust and informative perspectives. Their use in Land Use Functions (LUFs) (Pérez-Soba et al. 2008) allows them to be grouped, with weightings, in a system that represents meaningful impact assessment for both stakeholders and end-users.

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Weighting and aggregation of indicators for sustainability impact assessment in the SENSOR context

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Abstract

In response to the need for developing methods for evaluating multi-dimensional problems in sustainability assessment, the scientific literature provides many examples related to the theory and use of composite indicators. In the context of the SENSOR project, dealing with the ex-ante assessment of environmental, social and economic impacts of European policies on multifunctional land use, new constraints and dimensions are added to the exercise. Examples are the need for consistency across European regions and across different scales of analysis; the use of qualitative and quantitative information; the possibility of aggregation to different administrative levels (sensitive areas, Member States, cluster regions, EU); and the correct balancing of the sustainability dimensions.

As a basis for the development of a system of composite indicators, this paper presents a critical review of existing methods for the weighting and thematic aggregation of indicators, and considers the characteristics of selected approaches in relation to the needs of impact assessment in general and the SENSOR requirements in particular.

Keywords

composite indicators, weighting, aggregation, multi-criteria analysis, compensatory and non-compensatory analysis

1 Introduction

Sustainability is a complex issue, and it is probably easier to describe it with a large number of indicators rather than trying to condense it into a few. Even though scientists might be more interested in uncondensed data that can be statistically analysed, policymakers and the public generally prefer condensed data related to policy objectives and free of redundancy (Pacini et al., 2003). This opens the challenge of defining a coherent and universal methodological framework for sustainability indicators, which satisfies the demand of data integration consonant with the needs of sustainable development, while at the same time reflecting the multiple dimensions inherent in the concept of sustainability.

The difficulty at evaluating the environmental and socio-economic performance of so many indicators makes it necessary to reduce and combine them so as to make this information more accessible and easy to interpret (Kang, 2002). This is done by means of composite indicators which are the result of the combination of individual indicators into a single summarised index on the basis of an underlying model, so as to provide a multi-dimensional measure. Such a measure is useful for complex phenomena which otherwise could be hardly comparable (Tangian, 2006). Within the process of building composite indicators, the step of weighting and aggregation of indicators is crucial in all modelling frames where a large amount of information has to be condensed so that the final results are more easily comprehensible, while retaining all or most of the available information.

This paper provides an overview of methods for aggregation and weighting of indicators and for the evaluation of results. It explains which are the theoretical possibilities, in which context they are applicable, and which are the constraints. Finally, we put this into the context of SENSOR requirements.

2 Requirements of the Sustainability Impact Assessment Tool (SIAT).

In relation to the SENSOR framework, there are different perspectives through which the problem of data and indicator integration can be addressed. The SENSOR project deals with the assessment of sustainability of changes in land use driven by European policies, by synthesising assessment approaches for all three sustainability dimensions with quantitative tools where possible, but integrating qualitative information where essential. This must be done in a way that is at the same time transparent, scientifically sound, maintains the information content as much as possible, and provides the policy makers with clear interpretations of the impacts of EU policies on land use. The complexity of the problem is magnified by the focus on multi-functionality and the different scales at which sustainability is addressed (local, regional, European).

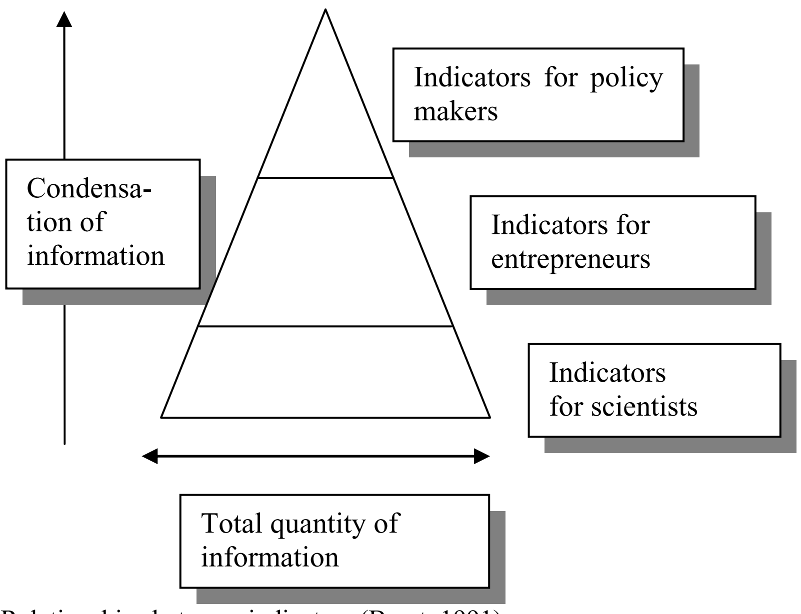

Fig. 1. Relationships between indicators (Braat, 1991)

The SENSOR indicator framework is located at the top of the pyramid shown in Figure 1, and is based on a selection of the impact issues listed in the EU Impact Assessment Guidelines (CEC, 2005) that have been judged relevant for the analysis of land use related impacts. The choice has been done with a view to maintain a balance among the three dimensions of sustainability, and a similar number of impact issues have been selected for each of the three sustainability pillars (economic, social, environmental) (Frederiksen and Kristensen, 2008). According to this list, appropriate indicators have been associated to each of the impact issues by a multidisciplinary expert panel; each indicator has been chosen according to its relevance for the selected topic (i.e. farmland birds for impact issue ENV6: Biodiversity, flora, fauna and landscapes) and data availability (both in the definition of the reference situation and within scenario modelling); the number of indicators that describe a single issue is variable. Land Use Functions (LUFs, i.e. Employment, Support and Provision of Habitat, Landscape Identity) have been defined to represent the goods and services that each land use provides, and that are linked to a set of indicators meaningful at the regional level. The LUFs are nine, balanced among the three pillars (Perez-Soba et al., 2008).

The aggregation and weighting of indicators has to be performed within a Spatial Regional Reference Framework (SRRF). The SRRF consists of twenty seven cluster regions that group the administrative regions of EU27, Norway and Switzerland according to the coherence of their biophysical and socio-economic characteristics (Renetzeder et al., 2008). The selected methodology for weighting and aggregation of indicators has to be sufficiently sound and elastic to be applicable in different environmental and socio-economic contexts, at the level of the SRRF clusters, but also at national and EU level.

A list of SIAT requirements, taking into account end-user requirements (requirements 1 to 5), the EC impact assessment (IA) guidelines (requirements 6 to 8) and SIAT internal consistency (requirements 10 and 11) is given below:

1. Transparency of processing methods of indicators (aggregation)
2. Effectiveness of indicator results' presentation tools in terms of condensation and non-redundancy of information
3. Possibility of aggregation of indicators on different spatial scales, sustainability themes and land use functions in order to get quick scan answers at different levels
4. Holistic approach
5. Possibility of performing sensitivity analyses of main parameters (and weights)
6. Ability to weight-up the positive and negative impacts for each option
7. Where feasible, display aggregated and disaggregated results
8. Present comparisons between options by area of impact (economic, environmental, social)

9. Identify, where possible and appropriate, a preferred option
10. Conceptual and data consistency between IA issues, LUFs and relevant indicators
11. Consistency between the macroeconomic, top-down approach and the regional, participative, bottom-up approach

The methodological thinking developed in SENSOR fixes some of the boundaries, that in other contexts may remain open: the nine LUFs set the limits of the aggregation needs; the LUFs equally represent the dimensions of sustainability, therefore it was implicitly decided that the three pillars can have equal weight, and this also sets the limits, as will be explained later, for the redistribution of weights to indicators within each LUF.

All the above mentioned requirements and constraints drive the selection of the method for aggregation and weighting of indicators. Finally, any of the choices will have underlying ethical implications (Munda, 2004), especially because the exercise is carried out in a policy frame, and addresses sustainability. Assigning weights, in fact, implicitly means assigning priorities, regardless of the selected method.

3 Weighting and aggregation techniques

The key steps in the condensation of multi-source information are: normalisation, weighting and aggregation.

Prior to normalisation, data analysis (through Principal Component Analysis and cluster analysis) may be necessary to explore data distribution, reduce the number of data dimensions and even to perform data aggregation, i.e. when areas characterised by common characteristics must be identified (see Metzger et al., 2005 for the definition of European Environmental Zones).

Normalisation is used to refer an indicator to a common dimensionless unit. It is essential to normalise data in view of aggregation procedures based on mathematical methods (i.e., linear aggregation). Different methods exist for data normalisation, namely standardisation, re-scaling, ranking and benchmarking (Nardo et al., 2005b). The latter is a relevant technique in the SENSOR context, since it is taking policy targets into explicitly. The operation is similar to re-scaling data (i.e., to a 0-1 scale) but in this case the reference value can be the best performer (or group leader), an ideal point of optimal performance, or a policy target. Benchmarking operations are also used as a method to assign weights, or as a way to maintain information on the intensity of preference in non-compensatory analyses. As a method for weighting, the benchmarking implies the identification of a target objective measured by the distance from the best performer (or group leader), or from an ideal point of optimal performance. In the first case the relative performances of alternatives (i.e. country performances, or composite indicators) are optimised, the further distant an alternative is from the goal, the higher the urgency of the problem. The weighting is obtained by means of dividing the sub-indicator values by the corresponding target values expressed in the same units (Saisana and Tarantola, 2002).

This type of approach opens the debate on how to define the targets. In the SENSOR context they will coincide with policy goals when possible (i.e. Lisbon Strategy, Water Framework Directive, Nitrate Directive etc.), though it must be underlined that setting a reference target for complex LUFs (i.e., Provision of Work) is not a trivial task.

According to Saisana (2007) weighting procedures can be framed in three main groups: weights based on statistical models; equal weighting; and weights based on participatory approaches. The variety of methods that can be used for performing this step is illustrated by a review of recent literature on the issue carried out as part of the present study. Within the papers reviewed, the majority of cases (12 out of 16) used a non equal weighting, mostly (10 out of 12) based on a participatory approach, and to a smaller extent (2 out of 12) based on statistical models; the remaining cases were based on equal weighting. The most frequent aggregation approach was additive, though in the case of three groups of indicators a more complex Multi-criteria Analysis (MCA) was applied.

Due to the characteristics of available data, statistical derivation of weights (e.g. PCA or regression analysis) is not applied in SENSOR. It is preferred to maintain a high degree of transparency in the overall process. The other two approaches (equal weighting and participatory) are relevant in the SENSOR context at different levels. A review of the possibilities and the constraints for the application of such methods against generic, EC impact assessment (IA) and SIAT internal requirements is given below. It is linked to the wider context of aggregation procedures. The listed approaches can be considered part of the wider group of methods for MCA, and its two main sub-groups: compensatory and non-compensatory MCA. Statistical/mathematical methods are reported separately.

3.1 Multi-criteria Analysis

Multi-criteria Analysis (MCA) – also known as multi-objective analysis – is an approach developed for complex multi-dimensional problems, which include qualitative and/or quantitative aspects of the problem in the decision-making process (Mendoza et al., 1999). MCA can also be defined as a decision support technique that aids decision-makers to evaluate resource allocation issues. It is increasingly being used in the policy arena, often as an alternative for cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) (Gillespie, 2000; Brouwer and Van Ek, 2004); "MCA is an approach rather than a single well defined procedure" (RAC, 1992) and refers to techniques that include the following three key components:

- A number of alternative plans or options that require evaluation;
- A set of criteria by which the alternatives are to be judged; and
- A method for ranking the alternatives based on how well they satisfy the criteria.

In general terms, the discrete multi-criterion problem is formulated by Munda (2004, 2005a) as following: A is a finite set of N feasible alternatives (a,b…N), M the number of evaluation criteria

$$g_m i = 1,2,\ldots,M \tag{1}$$

considered relevant. In this framework, the alternative a is evaluated to be better than alternative b according to the m^{th} point of view if

$$g_m(a) > g_m(b) \tag{2}$$

This information is recorded in an impact matrix which includes the number of criteria in favour of a given alternative, the scores of preference intensity if present, the weights of criteria and the relationship between alternatives.

We can distinguish between compensatory and non compensatory MCA depending on the use of weights in the aggregation: "In compensatory techniques poor performance in a number of criteria can be compensated for by high performance in the other criteria and may not be reflected in the aggregated performance of an option. In non-compensatory techniques poor performance in a number of criteria cannot be compensated for by high performance in the other criteria and will be reflected in the aggregated performance of an option" (Jeffrey, 2004, 2005a). When they are used with intensity of preference, weights are given the meaning of trade-offs and corresponding methods are called compensatory MCA methods. Indeed, compensability refers to the possibility of offsetting a disadvantage on some criteria by a sufficiently large advantage on another criterion, whereas smaller advantages would not do the same. Non-Compensatory MCA methods are those in which weights are used with ordinal criterion scores (Munda, 2004).

MCA procedures are distinguished from each other principally in terms of how they process the basic information collected in a performance matrix (Dodgson et al., 2000). The main step in data processing (after normalisation, when needed) is the aggregation of the single scores that each option receives against each criterion into an overall score used to rank the options. This step implies the attribution of relative weights to criteria by which the options are evaluated.

3.1.1 Compensatory Multi-Criteria methods

Dodgson et al. (2000) report a broad overview of the full range of MCA techniques currently available (or that have a potential) for public sector decision-making. They also select the better known compensatory methods: multi-attribute utility theory (MAUT), linear additive models, analytical hierarchy process (AHP), procedures that use qualitative data inputs; MCA methods including uncertainty. In the following an overview of such methods is reported. The applicability of these methods to the case of SIAT will be discussed in the next sections.

The multi-attribute utility theory (MAUT)

The multi-attribute utility theory provides the theoretical basis for multiple criteria methods. MAUT states that the overall utility of an option (an option's attractiveness to the decision-maker) can be derived from the sum of the measured values of its attributes. The attributes are transformed into single dimensionless utilities using utility probability functions. These probability functions are assessed for each attribute and are often complex. They are the basis for standardising functions used in many evaluation methods (Keeney and Raifa, 1976; Jeffrey, 2004).

Linear additive models

If it can either be proved or reasonably assumed, that the criteria are preferentially independent of each other and if uncertainty is not formally built into the MCA model, then the simple linear additive evaluation model is applicable. The linear model shows how option's values on the many criteria can be combined into one overall value. This is done by multiplying the value score on each criterion by the weight of that criterion, and then adding all those weighted scores together (Dodgson et al., 2000). Weights may be directly assigned or assigned using a ranking process or pair-wise comparisons that are usually embedded in the tool being used. The weighted summation technique is one of many methods included in Multi-attribute Utility Theory (Keeney and Raifa, 1976). Most MCA approaches use this additive model, and this is the basis of the MCDA approach (for a comprehensive description of the MCDA method reference is made to Dodgson et al., 2000).

The Analytic Hierarchy Process (AHP)

The AHP is a technique that involves structuring a multidimensional problem into a hierarchical tree with criteria and alternatives. This method enables decomposition of a problem into hierarchy and assures that both qualitative and quantitative aspects of a problem are incorporated in the evaluation process. During the evaluation process an opinion is systematically extracted by means of pair-wise comparisons, by firstly posing the question "which of the two indicators is more important?" and secondly "by how much?" The strength of preference per pairs of indicators is expressed on a semantic scale of 1 (equality) to 9, where 1 reflects the minimum importance in relation with the indicator to which it is compared (i.e. an indicator can be voted to be 9 times more important than the one to which it is being compared). Comparisons can be stored in a comparison matrix A, where

$$A_{ii} = 1 \tag{3}$$

$$A_{ij} = 1/A_{ji} \tag{4}$$

Then, the relative weight of the indicators is calculated using an Eigenvector technique, which allows to resolve inconsistencies, e.g., A better than B better than C better than A loops (Nardo et al., 2005). The limitations of the method are that the dimensions of the comparison matrix can be large when many indicators have to be compared pair-wise, that the assignment of weights requires an accurate selection of the experts involved and that the results are strictly linked to the context (not transferable).

Procedures that use qualitative data inputs

There are a number of procedures that use models that approximate the linear additive model but are based on ranking of weights. These procedures were developed to face the common lack of quantitative information in an MCA performance matrix. Certainly one of the most common procedures of this kind is SMARTER (Edwards and Barron, 1994). The SMARTER technique has three variations, namely SMART, SMARTS and SMARTER, referring to Simple Multi-attribute Rating Technique, Simple Multi-attribute Rating Technique using Swings, and Simple Multi-attribute Rating Technique Exploiting Ranks. Edwards and Barron asserted that SMART contained an error in logic, which was subsequently corrected in SMARTS. These techniques use linear approximation to standardise the scores to single dimensionless cardinal utility functions and a weighted additive aggregation function (Jeffrey, 2004).

MCA methods including uncertainty

A different response to the imprecision that surrounds much of the data on which public decision making is based has been to look to the developing field of fuzzy sets to provide a basis for decision making models. Fuzzy sets attempt to capture the idea that our natural language in discussing issues is not precise. Options are "fairly attractive" from a particular point of view or "rather expensive", not simply "attractive" or "expensive". Fuzzy arithmetic then tries to capture these qualified assessments using the idea of a membership function, through which an option would belong to the set of, say, "attractive" options with a given degree of membership, lying between 0 and 1. Building on assessments expressed in this way, fuzzy MCA models develop procedures for aggregating fuzzy performance levels, using weights that are sometimes also represented as fuzzy quantities (Dodgson et al., 2000).

Other alternative approaches coping with uncertainty are those trying to complement a standard MCDA approach with Bayesian belief networks (BBNs). BBNs are a tool for knowledge representation and reasoning under uncertainty in intelligent systems (Watthayu and Peng, 2004). BBNs consist of two components. The first is a set of boxes representing variables of the system being considered (called nodes) joined by arrows indicating causal links (called directed edges). The second component consists of tables of Bayesian probabilities expressing the likelihood that a variable is in a particular state given the states of any variables which effects it (called conditional probability tables) (Bacon et al., 2002). One example of how BBNs and MCDA approaches can be integrated in a complementary way is given by Fenton and Neil (2007). The procedure consists of identifying the objective and perspective for the decision problem, as well as the stakeholders, a set of possible actions, criteria (uncertain and certain) and constraints. The BBN links all the criteria and enables modellers to calculate a value (within some probability distribution in the case of the uncertain criteria) for each criterion for a given action. Following, traditional MCDA techniques can be applied to combine the values for a given action and then to rank the set of actions.

3.1.2 Non-compensatory Multi-criteria methods

The basis for non-compensatory Multi-criteria methods is the use of weights with ordinal criterion scores that gives the weights the meaning of importance coefficients and not of trade-offs (Munda, 2005b). A crucial point concerns the assignment of weights; in this regard there has been an evolution in the methodological development that has lead to the establishment of a whole typology of models that deal with participatory approaches, in particular when issues concerning sustainability are addressed (participative multi-criteria evaluation - PMCE, stakeholder multi-criteria decision aid - SMCDA, social multi-criteria evaluation - SMCE).

Non-compensatory/Non-linear Condorcet Consistent Composite indicators

This method is suited for ranking different options, like countries performances. It is based on a pair-wise comparison of the alternatives according to the whole set of individual indicators used, and the ranking of alternatives in a complete pre-order (Munda and Nardo, 2006). An outranking matrix is built where elements are the results of the pair-wise comparison between all possible combinations of alternatives (or countries) and according to all individual indicators. The maximum likelihood principle can be applied to select as final ranking the one with the maximum pair-wise support or, in the adaptation proposed by Munda (2005b) is the ranking supported by the maximum number of individual indicators for each pair-wise comparison, summed over all pairs of alternatives considered. The final result is a ranking of the different alternatives that does not take into account the intensity of preferences (unless benchmarking is done). The drawback of this method is that the number of permutations to be considered in the matrix is the factorial of the number of alternatives (i.e. 10 alternatives = 10! = 3628800 pairs). Recent developments, though, have lead to the creation of numerical algorithms that make it possible to apply the maximum likelihood ranking procedure. An example of this method has been proposed as an alternative for calculating the Environmental Sustainability Index (Esty et al., 2005).

ELECTRE

The ELECTRE methods (I, IS, II, III, IV) have been developed by Bernard Roy (Roy and Bouyssou, 2003) and are used in a context of selecting and ranking of problems (or projects). The goals of the ELECTRE approaches are very similar to those explained in the paragraph above, but the method differs in the way the pair-wise comparisons are done. They are based on outranking relations and introduce the concepts of thresholds. In practical terms, Option a is preferred to Option b when Option a is at least as good as Option b on the majority of criteria and when it is not significantly bad on any other criteria; the concepts of “at least as good” and “not significantly bad” are evaluated against a set of thresholds that classify the degree of preference: strong, weak, indifferent, veto. Furthermore, the concepts of “concordance” and “discordance” are added to the decision framework, in order to add a measure of the strength of the assertion that one option is better than another. Only when both the concordance and discordance tests are passed, can it be said that the outranking relation, that Option a is preferred to Option b, is true (Milani et al., 2006). It must be stressed that in this frame the thresholds and weights are arbitrary, while in the SENSOR context the thresholds may come from the definition of critical limits (Bertrand et al., 2008).

Social Multi-Criteria Evaluation

Social Multi-Criteria Evaluation (SMCE) is a type of MCA characterised by public participation in the decision process. Its enhanced transparency and its characteristics of multi-disciplinarity makes it particularly suited in contexts of policy analysis and public processes of decision making. As in other MCA methods, the alternatives are then compared in an outranking matrix. The participatory approach to define weights, assign priorities and evaluate scenarios can be adopted in the wider context of MCA. It is listed in the present paper among the non-compensatory methods, because of a specific reference to recent theoretical work developed by Munda (2004).

The issue of the assignment of weights acquires particular relevance in social multi-criteria evaluation, since the public component of the methodology requires complete transparency of the process, and representativity of all actors involved, including small minorities. This is particularly important since in this context indicators (or criteria, or minorities) linked to small weights can still influence the final results (Munda, 2004).

This also opens the debate on who the “actors” are, how they are selected and how well they represent all involved social groups. A possibility is to act through methods of sociological research, and to identify, through an institutional analysis, the relevant social actors (Munda, 2005b and Munda, 2006a). This approach allows for a change in the scale of the analysis (i.e., regional to European), when stakeholders of the corresponding level are involved.

3.2 Mathematical/statistical methods

3.2.1 Multiple Linear Regression Models

Multiple Linear Regression involves the analysis of relationships between three or more variables. It assumes that the relation between the variables is a linear function of some parameters. Considering Y as the variable of main interest and X_k the remaining variables, the multiple linear regression equation would be as follows (Edwards, 1976):

$$Y' = a + b_1 X_1 + b_2 X_2 + \ldots + b_k X_k \tag{5}$$

Where a, b_k are the regression parameters to be found that maximize the correlation between the observed values of Y and the predicted values Y'. In its application to composite indicators, these regression parameters are considered the weighting coefficients, while Y' represents the composite indicator and X_k the sub-indicators.

In this case, as for PCA, the weights are empirically deduced and depend strictly on the input data, therefore in a scenario analysis frame they would change according to each scenario.

3.2.2 Benefit of the Doubt Approach

The Benefit of the Doubt Approach started with the implementation of Data Envelopment Analysis (DEA) in the field of economics. As such, DEA employs linear programming tools to estimate an efficiency frontier to be used as a benchmark to measure the relative performance of the analysed actors (e.g. scenarios, countries), which is calculated as the distance between the position of the actors and the benchmark (the efficiency frontier) in a multi-dimensional space.

The idea behind the Benefit of the doubt approach is that a good relative performance of a country in one particular sub-indicator dimension indicates that this country considers the policy dimension concerned as relatively important (Cherchye et al., 2007a and 2007b).

In this technique the weights, in term of sustainability indicators, correspond to proportions between indicators. This makes it suited to monitor the progress in country performances towards the best overall performance, and is the main reason why the Benefit of the Doubt has a good political acceptance.

4 Discussion

In Table 1 a list of requirements of sustainability impact modelling is reported as it has been settled for the construction of the SIAT model (Sieber et al., 2008) and explained in the section on the requirements of the SIAT.

In the following, the methods selected in this paper are critically reviewed against such modelling requirements in order to evaluate which methods fit better a modelling framework for sustainability impact assessment when aggregation of results and presentation are concerned.

Table 1. Assessment of SIAT requirements for the weighting and aggregation methods

Nr	SIAT[1] requirements	Compensatory Multi-criteria Analysis			Non-compensatory MCA[6]		Mathematical and Statistical methods	
		MAUT[2]	BLAM[3]	AHP[4]	SMARTER[5]	MCA[6] with uncertainty		
1	Transparency of aggregation methods of indicators	Y[7]	Y	Y	Y	N[8]	Y	N
2	Effectiveness of indicator results' presentation tools in terms of condensation and non-redundancy of information	Y	Y	Y	Y	Y	Y	Y
3	Possibility of aggregation of indicators on different spatial scales, sustainability themes and land use functions in order to get quick scan answers at different levels	Y	Y[9]	Y[9]	Y[9]	Y[9]	Y[9]	N
4	Holistic approach	N.A.[10]	N.A.	N.A.	N.A.	N.A.	Y[9]	N.A.
5	Possibility of performing sensitivity analyses of main parameters (and weights)	Y	Y	Y	Y	Y	Y	Y
6	Ability to weigh-up the positive and negative impacts	Y	Y	Y	Y	Y	N.A.	N.A. (N)
7	Where feasible, display aggregated and disaggregated results	Y	Y	Y	Y	Y	Y	Y
8	Present comparisons between options by area of impact (economic, environmental, social)	Y	Y	Y	Y	Y	Y	Y[9]
9	Identify, where possible and appropriate, a preferred option	Y	Y	Y	N	Y	Y	Y
10	Conceptual and data consistency between IA[11] issues, LUFs[12] and relevant indicators	Y	Y	Y	Y	Y	Y	N
11	Consistency between the macroeconomic, top-down approach and the regional, participative, bottom-up approach	N	Y	N	N	N	Y[9]	N

[1] Sustainability impact assessment tool, [2] Multi-attribute utility theory, [3] Basic Linear Additive Models, [4] Analytical Hierarchy Process, [5] Simple multi-attribute rating technique exploiting ranks, [6] Multi-criteria analysis, [7] Yes, [8] No, [9] Subject to applicability of assumptions, [10] Non-applicable, [11] Impact assessment, [12] Land use functions

Requirement 1

Although MAUT retains notable advantages in terms of conceptual coherence and inclusion of uncertainty, the way in which data are processed for aggregation and weighing under MAUT is relatively complex and does not fit a public of non-specialists. In other words, results produced by MAUT are more reliable from a scientific perspective but less transparent for end-users. Simple linear additive models as used e.g. in MCDA are by far more direct. Changing values of weights to perform sensitivity analysis and look at changes of the ranking of policy option is easy; corresponding algorithms can be included in a model architecture without any complication.

Although more data demanding, the AHP method offers a good level of transparency as it is clear that users generally find the pair-wise comparison form of data input straightforward and convenient (Dodgson *et al.*, 2000). The same holds for procedures that use qualitative data inputs such as SMARTER, which allows a strong involvement of stake-holders/experts but at the cost of a high demand of data input. MCA methods based on fuzzy sets deal also with qualitative data and participation but, although they are intuitively well perceived by stake-holders experts, they do not have clear conceptual foundations from the perspective of modelling decision makers' preferences. On the other hand, BBNs in combination with MCDA techniques do not hold a high level of transparency as they imply the use of complex Bayesian probability matrices.

Non-compensatory MCA methods, in particular SMCE, are developed with the specific scope of enhancing transparency, therefore they fully fulfil the criterion. Mathematical/Statistical methods, lack transparency and results are interpretable only by specialists.

Requirements 2, 5, 6, 7, 8 and 10

In general all MCA methods (compensatory and non-compensatory) meet most of the requirements of Table 1 (Requirements Nr. 2, 5, 6, 7, 8 and 10). In fact, MCA has been developed with the specific purpose to deal with multi-dimensional problems such as those of sustainability. Subject to applicability of corresponding assumptions (see requirement 3), all the methods allow for aggregation of indicators and LUFs and, therefore, for the condensation of information. Non-redundancy does not depend on the aggregation method used but on the choice of criteria/LUFs/indicators selected for SIA (requirement 2). Sensitivity analysis of single indicators, composite indicators and relevant weights is a common step in all MCA exercises (requirement 5).

Mathematical/statistical approaches are appropriate for aggregation, condensation and reduction of redundancy. From a purely mathematical point of view they maintain data consistency between different levels of aggregation, but lack conceptual consistency, since the aggregation procedure is not transparent (except for the Benefit of the doubt approach).

IA assessment requirements such as weighing-up of positive and negative effects, aggregation and dissagregation of results, and presentations of comparisons by area of impact (or LUF, requirements 6 to 8,) are all possible under MCA techniques. In fact, EC guidelines advise the use of MCA methods for IA of policy regulations (European Commission, 2005). Furthermore, provided that there is conceptual and data consistency between IA issues, LUFs and relevant indicators in the SIAT, aggregation with Multi Criteria Analysis (MCA) techniques is always feasible (requirement 10).

Requirement 3

Aggregation on different spatial scales depends on the spatial reference of each indicator and is not treated here. In principle MCA allows for aggregation of indicators into LUFs and sustainability themes. However, aggregation is subject to assumptions specific to each method.

In the case of Multiple Linear Regression Models, as for PCA, the weights are empirically deduced and depend strictly on the input data. In a scenario analysis frame they would, therefore, change according to each scenario, making it impossible to compare different situations.

The only MCA compensatory method that guarantees the possibility of aggregation on a broader range of conditions is MAUT. This method has a strong theoretical background (von Neumann and Morgenstern, 1947; Savage, 1954; Keney and Raiffa, 1976), and includes analyses with uncertainty and mutual dependence of preferences.

MCDA, which is based on a basic linear additive model, is subject to an assumption of mutual independence of preferences of criteria and does not take into consideration uncertainty. However, when MCA is combined with a coherent framework of criteria, LUFs and indicators, and with a modelling approach for the calculation of indicators (see Brouwer and van Ek, 2004 for an example), mutual independence of preferences can be reasonably assumed. Furthermore, uncertainty in all MCA methods can be alternatively tackled by sensitivity analysis or including BBNs.

Many of the previous remarks on MCDA are shared by AHP, at least in the case of a fixed set of policy options to be evaluated. As a matter of fact, serious doubts have been raised about the theoretical foundations of the AHP and about some of its properties. In particular, the rank reversal phenomenon has caused concern. This is the possibility that, simply by adding another option to the list of options being evaluated, the ranking of two other options, not related in any way to the new one, can be reversed.

This is seen by many as inconsistent with rational evaluation of options and thus questions the underlying theoretical basis of the AHP (Dodgson et al., 2000).

In addition to remarks on MCDA, procedures that use qualitative data inputs such as SMARTER and MCA methods based on fuzzy set, share the disadvantage that they are based on imprecise information and this can cause a further decrease of the level of accuracy of the indicator aggregation. In fact, such methods should be solely used when quantitative information is not available and, anyway, if possible, in combination with quantitative methods.

Non-compensatory MCA methods allow in principle for aggregation at different scales, but since they are quite complex to implement they are generally not suited for quick scan answers, especially when the participatory approach is involved.

Requirement 4

As for requirement 4, it has to be stressed that whatever aggregation is carried out between indicators, LUFs or other sustainability dimension, it will always intrinsically contain a reductionist approach. Information is condensed and consequently a comprehensive and systemic way of interpretation of phenomena is contrasted. However, presenting results in an aggregated way does not mean that results of single indicators/LUFs cannot be shown separately, giving a whole, holistic picture of the sustainability impact.

The main differences between the presented methods concern requirements 1, 3, 9 and 11. In the following such differences are discussed.

Requirement 9

A strength of MCA compensatory and non-compensatory methods is that they allow for the identification of the best among the options and the rank of all of them. As recalled by the EC IA guidelines, this is certainly valuable for any policy comparison exercise. The EC IA guidelines give indications on the final choice to be made among the selected policy options. It is specified that the final choice is always left to the College of Commissioners; however, the decision support system must provide the Commissioners with a rank of options made according to a number of criteria, with the results presented in a transparent and understandable way to provide the basis for a political discussion on the relative advantages and disadvantages of the each option (European Commission, 2005).

All MCA methods supply users with a preferred option, however, as far as procedures that use qualitative data inputs are concerned, a number of extra assumptions have to be made, if a single preferred option is to be identified, or even a ranking of options (Dodgson et al*.,* 2000).

Among the Mathematical/Statistical methods the one that provides a sound ranking of the options is the Benefit of the Doubt Approach.

Requirement 11

Where a specific local problem of sustainable land use can not be assessed with tools at pan-European level, while being of major importance for a sustainable rural development of a given region. A regional, more participative, bottom-up approach is needed. This regional approach should be embedded in a broader, pan-European SIA in order to allow for comparison between the SIA at local scale and that at higher hierarchical levels. Such a comparison would be fundamental for the application of the subsidiarity and proportionality principles.

To allow for comparisons between regional and pan-European levels, common methods should be used, though this is difficult to achieve as the level of detail of the analysis and the profile of the stakeholders involved can be very different. Hence, flexible, straightforward and easily replicable methods should be used.

An advantage of MCDA based on linear additive models in comparison with the other MCA compensatory methods is that this method has a well-established record of providing robust and effective support to decision-makers working on a range of problems and in various circumstances (Dodgson et al., 2000). As such it is a good starting point for the development of participatory, bottom-up analyses for local SIAs, like those based on group valuation or deliberative processes (Heine et al., 2006; O'Neill, 2001; Stagl, 2006). Changing the level of detail from regional to pan-European, the same MCDA approach can be replicated by replacing local stake-holders with EU experts (or continental representatives of stakeholders); this obviously perfectly applies to SMCE, as it that makes the participatory approach its main characteristic.

Stakeholder/expert involvement in the MCA exercise is fundamental not only in the case of specific, local problems, but also from a SIA, large-scale, modelling perspective because it complements a knowledge based framework and supplies end-users with generic reference points from which to start a sensitivity analysis. The more participatory is the mechanism of computation of the policy options' ranks, the more legitimate it will be in the view of end-users.

Stakeholders and experts can be involved in the MCA process at different stages, i.e. for the selection of policy options, objectives/criteria, indicators, indicators targets/thresholds and for the attribution of weights. Whatever their level of inclusion is, an important (although often forgotten) step in building the MCA exercise is the assembling of a balanced group of panellists to be consulted in the decision-making process. In this case "balanced" means consistent and coherent with the extent of the object of the MCA exercise and with the actors involved.

Even if mathematical/statistical methods would allow the same from a computational point of view, the methodological relations between scales and indicators would depend solely on the data and would, therefore, remain complex to identify and analyse.

5 Conclusions

From the analysis of Table 1 it emerges that two methods fulfil all requirements of the SENSOR community: MCDA based on linear additive models and non-compensatory MCA.

The choice on which method to select is driven principally by the requirements of SIAT and its envisaged structure, which has been developed in order to meet the end-user (i.e., policy makers at the European level) and EC IA guidelines requirements.

An important component of the SIAT process is that critical limits related to sustainability thresholds are set for each impact indicator. Therefore, it should be possible at any moment to take such information into consideration, and in a hypothetical perfect aggregation frame it should also be possible not only to assess if a single indicator is trespassing it in relation to a specific scenario, but also to transmit such information through the aggregation and weighting chain. As mentioned in the paragraph on benchmarking, for example, it would be useful to refer each land use function to its specific critical limit which would be a composite figure derived from the single indicator limits.

A further requirement is that methods to rank the options by groups and/or by sustainability dimension should be included, in order to allow the possibility to address trade-offs (Sieber et. al., 2008). Furthermore, conceptual and data consistency between impact assessment (IA) issues, land use functions (LUF), dimensions of sustainability and indicators must be guaranteed. The main goal of SIAT is to assess the policy impact on the multi-functionality of land use. Consequently, there is a specific request for understanding the trade-offs between the social, economic and environmental dimensions of sustainability. This does not necessarily mean that compensability is allowed. In fact in a sustainability frame compensability is problematic, but the tool should include the ability to make trade-offs transparent.

On the basis of this, it can be assumed that some basic requirements of the aggregation and weighting method should be to avoid rank reversal (since it is likely that new scenarios will be added frequently), to give a clear representation of intensity of preferences, and to allow for the management of quantitative but also qualitative indicators.

All this considered, linear additive methods could provide the necessary frame for performing all the above mentioned operations, while obeying all (or most of) the constraints. In this respect, a particularly difficult issue is guaranteeing the mutual independence of relations among the variables (or indicators) involved, not only in reference to the linking of indicators to LUFs (especially if each indicator contributes to the definition of more than one LUF), but also to the relations existing among LUFs. This is a very difficult issue to solve, given that it is already stated in the SENSOR frame that each LUF has a "prevalent" social, economic or environmental character and that a sharp distinction between the three sustainability pillars does not exist.

In order to deal with the compensability problem in linear aggregation, Munda (2004) suggests as a possible strategy giving equal weights to the dimensions of the problem and redistributing the scores across the indicators. Taking the example of sustainability this would imply consideration of the three dimensions of sustainability as equally important, so that each of them would globally score 0.333. Then, weights are redistributed according to the LUFs and the number of indicators for each function. If, for instance, there are four indicators in the LUF "Cultural" they would score 0.0275 each, to give a total of 0.111, and the same applies to the other indicators for the other dimensions concerned (Figure 2).

In the presented case one indicator is associated with one LUF, reducing the risk of having mutual dependence of indicators (which is not necessarily the case in the SENSOR context). Once the weights are assigned, the aggregation functions can be more or less complex. This frame could be applied at different scales and would guarantee consistency through the scales of analysis, but could not guarantee that the peculiarities of the regional situations are taken into account, unless a different internal organisation of indicators is implemented (a possible result, for example, would be that some indicators are not relevant at the local context and could be ignored).

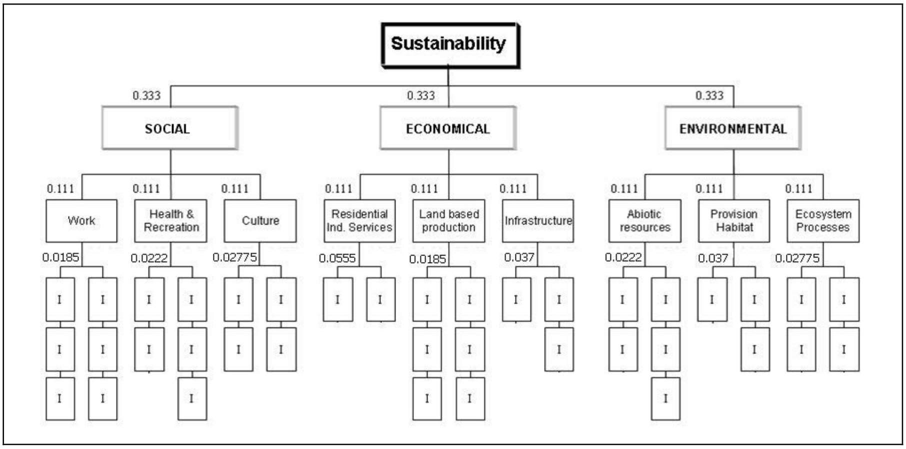

Fig. 2. Example of weighting strategy applicable in the SENSOR context

A more complex frame would assign the distribution of weights within each sustainability pillar or LUF, according to different criteria, for example a panel (or expert) decision. This, performed at the level of SENSOR's Spatial Regional Reference Framework, would take into account spatial variability of the factors driving sustainability across Europe. This could be the case in the analysis of impacts at the regional level when there is a direct involvement of stakeholders. Through an institutional analysis the same could be applied at a different scale; consistency through scales of analysis would then be guaranteed. If the same weight is applied to each pillar, it is assumed that there is no compensability among the dimensions of sustainability.

The selection of the best alternative is always possible with all presented methods and it can be compared against sustainability thresholds and limits, but the ranking of alternatives from a theoretical point of view should only be done in a non-compensatory frame (Munda, 2006b).

In conclusion, regardless of the selected method, transparency of the aggregation/weighting process and selection of the best alternative is highly recommendable in a sustainability assessment exercise. It should be possible to trace back and to put in evidence, at any moment, the elements that have driven the final choice. This ensures that the ethical dimension, which is overarching the multifaceted aspect of sustainability, is taken into account.

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Part V

Regional and local evaluation

Land use functions – a multifunctionality approach to assess the impact of land use changes on land use sustainability

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Abstract

The dramatic changes in land use observed in Europe in the last fifty years have generally resulted in improvement of human welfare and economic development. On the other hand, they have caused serious environmental problems. There is therefore a need for approaches that help to understand in an integrative way the economic, environmental and societal impacts that land use changes have on sustainability. Sustainability Impact Assessment (SIA), which assesses the impact of policies on sustainability,

addresses this challenge. SIA partly builds on the concept of the multifunctionality of land which helps to deal with the complexity of interactions between different land uses, their temporal and spatial changes, and finally how policies might steer those changes towards sustainability. Following this need for true integration of economic, environmental and societal issues across policy areas at a meaningful spatial scale, an interdisciplinary team in the SENSOR project has developed an innovative conceptual framework to assess the impact of policies on land sustainability at various levels of spatial aggregation i.e. the Land Use Functions (LUFs) framework. LUFs are the goods and services provided by the different land uses that summarise the most relevant economic, environmental and societal issues of a region. The LUFs framework integrates the changes observed in a large set of impact indicators into nine Land Use Functions (LUFs), which are balanced among the three pillars of sustainability. The LUFs framework makes it possible for policy makers, scientists and stakeholders to identify at a glance those functions of the land which are hindered or enhanced under various scenarios of land use change, and makes it possible to explore the trade-offs between them. The LUFs framework allows therefore the building of assessment across disciplines, sectors and the three sustainability dimensions. It has proved to be very helpful for the systematisation of relevant sustainability indicators within SENSOR and is intended to be further used in other projects as a tool for Sustainability Impact Assessment. The rationale leading to the LUFs concept, its definition and the conceptual framework is described in this chapter. We conclude that the concept of LUFs allows users to make explicit the analytical links between multifunctional land use and sustainable development, and therefore to look at multifunctionality as a way towards sustainability.

Keywords

Land use change, Land Use Function, regional impact assessment, Sustainability Impact Assessment, multifunctionality.

1 The need for integrative approaches in Sustainability Impact Assessment and explicit links to multifunctionality

Land use in Europe has changed drastically during the last fifty years (ESA SP 2006) usually in relation to human well-being improvement and economic development, while unfortunately causing serious environmental problems (EEA 2005). To understand the impacts of these land use changes on sustainability is currently a major challenge for the policy and scientific community. One approach developed to address this challenge is Sustainable Impact Assessment (SIA) and its application at the level of policies. The Impact Assessment guidelines of the EU (CEC, 2005) and the renewed and comprehensive EU Sustainable Development Strategy launched in June 2006 (CEU 2006) represent certainly a valuable modus operandi for achieving sustainable development in the European territory. Probably the most novel aspect is that the guidelines clearly state that SIA should perform a real integration of economic, environmental and social issues across policy areas. Indeed former methods - Environmental Impact Assessment (EIA), and Strategic Environmental Assessment (SEA) - considered environmental issues separately from social and economic ones. On the one hand, this may give the socio-economic issues additional 'weight' in decision-making and help them to keep the integrity of the environmental assessment. On the other hand, the SIA appraisal more closely reflects actual policy decision-making, and is required by the EU, and therefore integrating the two procedures makes sense in terms of efficiency.

The integration of economic, environmental and societal issues in SIA requires an interdisciplinary team, challenging existing paradigms and daring to break basic taboos such as the conflict of reductionism against the complexity of reality. SIA tools demand complex systems of thinking based on intellectual synergy across boundaries (multi-scale integrated analysis), and not a collection of independent analyses, each based on a well-defined discipline and 'stitched together' in the final outcome (Winder, 2003). Moreover, SIA has to be performed at the appropriate spatial scale. For example, it has been argued that policies aimed at the direct provision of public goods have to be applied at a higher spatial resolution than agricultural policies aimed at agricultural products, which have been designed for the whole European Union (Reig, 2006). The reason is that the environmental services provided by agricultural activity may vary among countries and regions depending on their agricultural systems and social welfare functions. Therefore, there is a clear need for tools that allow a SIA at the appropriate regional scale.

In addition to sustainability, multifunctionality has also become a guiding principle of current EU policies. Indeed, it is deemed important to understand the complexity of the interactions between the multiple uses of land, their temporal and spatial changes, and finally the significance that policies might have on steering those changes towards sustainability. Stakeholder preferences need to be considered as well, when linking the multifunctional to the sustainability concept. The concept of multifunctionality must therefore be defined in relation to land use and needs to take into account the human perception of change. This allows us to identify in a given context the relevant goods and services provided by land use.

In conclusion, there is a need for a conceptual framework that (i) adequately defines and measures the economic, environmental and societal goods and services - functions - provided by the multiple use of the land at a territorial level; (ii) helps to identify the sustainability limits/ thresholds/ targets of these functions; and (iii) investigates the impact that policy options might have on the conditions for land use sustainability in the different regions of Europe. An interdisciplinary team within SENSOR has addressed this need by developing the Land Use Functions (LUFs) conceptual framework, which integrates the changes observed in a large set of key economic, environmental and socio-cultural indicators that are meaningful at regional level, into nine single Land Use Functions.

The objective of this chapter is to describe the conceptual framework as it is currently developed within the project. Firstly we present the evolution of the 'functional' concept concerning good and services of the land; secondly we define the Land Use Function concept and the nine functions considered in SENSOR; thirdly we describe the conceptual LUFs framework to be implemented into an integrated impact assessment at regional level; and finally we discuss the main advantages of the LUFs framework and further steps to accomplish it.

2 Evolution of the 'functional' concept

The conceptual framework of Land Use Functions is a functional analysis on how changes in policy may impact on the performance of the multiple functions attached to land use. The LUF concept responds to the growing need for methods to evaluate changes in sustainability in a way that reflects the multiple dimensions inherent to the concept (Kates et al, 2001; Tress et al, 2005). One of the main challenges is to evaluate simultaneously economic, environmental and social impacts that are expressed by large sets of indicators. This calls for a reduction of the number of dimensions represented by the set of indicators to make the sustainability assessment interpretable. The LUF concept has its main roots in the concepts of multifunctionality in agriculture, ecosystem good and services and landscape functions.

From a chronological point of view (Helming et al., 2008), the *multifunctional concept* has its origin in the agricultural sector and became an important scientific issue in the late 1990s following changes in agricultural policies at global (FAO, OECD, WTO) and European scale (EU Common Agricultural Policy). It has several interpretations depending on the extent of the 'agriculture term' (e.g. agricultural practices, forestry, rural areas, etc.) and on the functions considered, that can be various (e.g. public goods, employment, etc). The Multifunctional Agriculture (MFA) concept makes possible the integration of multiple (new) functions within agriculture and their interrelations within a rural development context and therefore is often implicitly associated with the concept of sustainable development. However, there are few studies that make explicit the relations between the two concepts. Most of the studies show partial links between agricultural production and pollution, biodiversity, landscape, animal welfare, recreation, rural employment, etc. Only a few studies deal in a comprehensive way with the multifunctionality concept (Vereijken, 2002) and even fewer address the consequences of multifunctionality for policy making (Ploeg and van der Roep, 2003; Knickel et al., 2004). The MFA concept has progressively developed into a more generic multifunctional land use concept (Oostinde et al. 2006) and it is now widely recognised that agriculture is not the only sector with multifunctional features Hediger (2006).

The recognition that land use changes, as other drivers of change, affect multiple dimensions of sustainability has been considerably boosted by the appearance of the *concept of ecosystem goods and services* (Constanza et al, 1997) or *functions* (De Groot et al., 2002). This concept supports the idea that semi natural ecosystems provide many goods and services to human society that are of ecological, socio-cultural and economic value. This framework has a high international profile because it is the methodological framework underlying the Millennium Ecosystem Assessment (MEA, 2003), and it was used as background to derive the concept of *landscape functions* in a first stage of the SENSOR project (Hein and De Groot, 2005), which was further developed by Kienast et al (2007). The concept of functions is particularly useful in sustainable land development as a framework to identify the multiple environmental, social and economic functions of land use (Wiggering et al., 2003; De Groot, 2006). Within SENSOR, the concept of ecosystem functions was outlined as a possible initial framework that could be adapted and implemented for the regional assessment of sustainability (Hein and De Groot, 2005). However, this approach presented fundamental discrepancies with the SENSOR philosophy, i.e. the ecosystem function based approach is concerned with how environmental quality influences human well-being and assumes that the environment affects society and economics. It requires a two-step approach where the social and economic impacts of changes in ecosystem functions are assessed through a participative approach. On the other hand, the SENSOR approach aims - within the framework of SIA – at assessing the direct impact of land use change on the three dimensions of sustainability, without adopting an 'environmental' view of the world. In addition, the landscape function approach considers landscape as a holistic concept which includes the physical, biological and human properties of a specific parcel of land and represents a higher spatial aggregation level than land use. Landscape functions act therefore as a link between land use and the goods and services provided by the use of the land to society (Kienast et al., 2007). This concept makes a clear separation between the social/cultural and the natural/cultivated capital of a society and focuses mainly on the last one. The sustainability assessment based on landscape functions is therefore substantially biased towards the environmental pillar (Kienast et al., 2007).

In order to avoid the bias inherent in using landscape functions, and in order to provide a balanced approach towards the three pillars of sustainability, the concept of Land Use Functions was developed as a next step in the regional sustainability assessment definition process of the project. The *Land Use Function* concept was defined therefore to (i) link directly the socio-economic functions (and not only the environmental) to the use of the land; (ii) provide a smaller - a landscape is a mosaic of land uses- and clearly defined spatial resolution, which avoids the discussion raised within the scientific community about landscape definition i.e. the dualism between the mainly bio-physical characterised landscapes (the 'touchable' landscapes) and the landscapes as areas perceived by people (the 'intangible' landscapes); and (iii) transparently address the identification of the different functions that a specific land use might have, facilitating the unambiguous analysis of their trade-offs. For example, forest land use might have several economic, environmental and societal functions such as provision of employment, provision of wood for forestry industry and/or for renewable energy, have a recreational function, be part of a cultural landscape, regulate the supply and quality of air, water and minerals, support biodiversity in the form of landscape cohesion and maintain ecosystem processes.

3 Definition of Land Use Functions

Land Use Functions (LUFs) are defined as the private and public goods and services provided by the different land uses, that summarise the most relevant economic, environmental and societal aspects of a region. Some of the 'non-commodity' functions can be considered as externalities or public goods. This definition is consistent with the definition of multifunctionality used by the OECD (2001). Each LUF is characterised by a set of key indicators that assess the ‘impact issues’ defined in the EU Impact Assessment Guidelines (CEC, 2005). The indicator values are provided after running the various scenarios of land use change through the macro-economic, sectoral and land use allocation models chain in SENSOR (Jansson et al., 2008). The changes in the indicator values may significantly affect the LUFs by enhancing or hindering the function, e.g. an increase in forest fire risk may hinder the support and provision of biotic resources in a region.

The LUFs concept allows therefore translation of the European assessment into an integrated regional impact assessment, i.e. the individual values of the indicators characterising a region that are obtained from the model chain are aggregated to assess the impact on the LUFs. In other words, the impacts on land use predicted by modelling of policy cases are measured by changes in a set of key indicators that build up the LUFs, and summarised in one single value per LUF. Consequently, the LUFs express in a compressed way the impacts caused by a policy option on the functionalities of the main land uses in a region and tackles the progress from IA to SIA (Fig. 1). The outcomes for sustainability are predicted by comparing the values of the indicators with their correspondent sustainability limits/thresholds and analysing how the policy option stimulates or hinders the LUF.

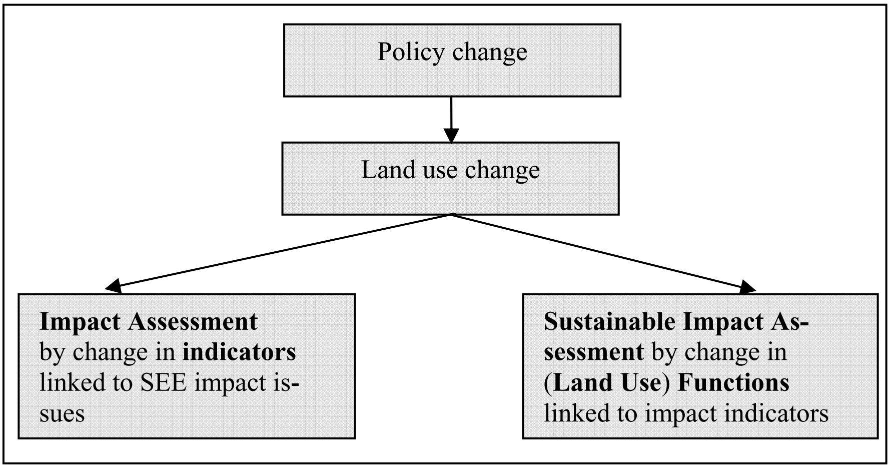


Fig. 1. The role of the LUFs concept in the evolution from Impact Assessment, based on indicators linked to societal, economic and environmental impact issues, to Sustainable Impact Assessment based on Land Use Functions

We have defined nine LUFs within the SENSOR context that are balanced among the three pillars of sustainability. They are summarised in Table 1. The nine LUFs were identified by an interdisciplinary group of experts considering the following criteria:

(i) they should have a clear relationship with the impact issues listed in the Impact Assessment Guidelines of the European Commission (CEC, 2005);
(ii) they should tackle the main spatially relevant economic, environmental and societal impact issues of those sectors involved in land use at EU level, i.e. agriculture, forestry, transport, energy, tourism and nature conservation (sectors considered in SENSOR).

Table 1. The nine Land Use Functions defined in SENSOR

Mainly SOCIETAL	Mainly ECONOMICAL	Mainly ENVIRONMENTAL
Provision of work	Residential and land independent production	Provision of abiotic resources
Human health and recreation	Land based production	Support and provision of biotic resources
Cultural	Transport	Maintenance of ecosystem processes

The definitions of the LUFs are as follows:

3.1 Mainly societal LUFs

LUF 1 Provision of work: employment provision for all in activities based on natural resources, quality of jobs, job security, and location of jobs (constraints e.g. daily commuting).This LUF is mainly affected by economic and societal impact issues, such as summarised in Table 2.

LUF 2 Human health & recreation (spiritual & physical): access to health and recreational services, and factors that influence services quality. This LUF is affected by the impact issues mentioned in Table 2.

LUF 3 Cultural (landscape identity, scenery & cultural heritage): landscape aesthetics and quality and values associated with local culture. This LUF is stimulated or hindered by impacts such as presented in Table 2.

3.2 Mainly economic LUFs

LUF 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. This LUF expresses the impacts such as listed in Table 2.

LUF 5 Land-based production: provision of land for production activities that do not result in irreversible change, e.g. agriculture, forestry, renewable energy, land-based industries such as mining. This LUF summarises impacts such as those described in Table 2.

LUF 6 Transport: provision of space used for roads, railways and public transport services, involving development that is largely irreversible. This LUF expresses changes in impacts issues such as presented in Table 2.

3.3 Mainly environmental LUFs

LUF 7 Provision of abiotic resources: the role of land in regulating the supply and quality of air, water and minerals. This LUF expresses changes in impacts issues such as those shown in Table 2.

LUF 8 Support & provision of biotic resources: factors affecting the capacity of the land to support biodiversity, in the form of the genetic diversity of organisms and the diversity of habitats. This LUF addresses changes in impacts issues such as: indicated in Table 2.

LUF 9 Maintenance of ecosystem processes: the role of land in the regulation of ecosystem processes related to the production of food and fibre, the regulation of natural processes related to the hydrological cycle and nutrient cycling, cultural services, and ecological supporting functions such as soil formation. The performance of this LUF is changed by impacts on issues such as mentioned in Table 2.

Table 2. Links between the LUFs and the Impact Issues of sustainability of land use that they tackled, as listed in the EC Impact Assessment Guidelines (CEC, 2005). Examples are provided.

LUFs	Impact Issues	Examples
LUF 1 Provision of work	Innovation and research (ECO 6)	Introduction and dissemination of new production methods, technologies and products, academic or industrial research and resource efficiency
	Specific regions or sectors (ECO 8)	Effects on certain sectors, on certain regions, for instance in terms of jobs created or lost, SMEs
	Public authorities (ECO 10)	Budgetary consequences for public authorities at different levels of government and establishing new or restructuring existing public authorities

LUFs	Impact Issues	Examples
	Macroeconomic environment (ECO 11)	Consequences of the option for economic growth and employment, conditions for investment and for the proper functioning of markets and inflationary consequences
	Employment and labour markets (SOC 1)	New job creation or loss, consequences for particular professions, groups of workers, or self-employed persons, demand for labour and functioning of the labour market
	Access to and effects on social protection, health and educational systems (SOC 9)	Impact on education and mobility of workers, access of individuals to public/private education or vocational and continuing training, co-operation in border regions
LUF 2 Human health & recreation	Operating costs and conduct of business (ECO 3)	Access to finance
	Consumers and households (ECO 7)	Quality and availability of the goods/services they buy, and on consumer choice, consumer information and protection, financial situation of individuals / households, both immediately and in the long run, economic protection of the family and of children
	Public authorities (ECO 10)	Budgetary consequences for public authorities at different levels of government and establishing new or restructuring existing public authorities
	Air quality (ENV 1)	Effect on emissions of acidifying, eutrophying, photochemical or harmful air pollutants that might affect human health, damage crops or buildings or lead to deterioration in the environment (polluted soil or rivers etc)
	Water quality and resources (ENV 2)	Effect on the quality or quantity of freshwater and groundwater, quality of waters in coastal and marine areas (e.g. through discharges of sewage, nutrients, oil, heavy metals, and other pollutants), drinking water resources
	Public health and safety (SOC 7)	Affect the health and safety of individuals/populations, including life expectancy, mortality and morbidity, through impacts on the socio-economic

LUFs	Impact Issues	Examples
		environment (e.g. working environment, income, education, occupation, nutrition), the likelihood of health risks due to substances harmful to the natural environment, health due to changes in the amount of noise or air, water or soil quality in populated areas,
	Tourism pressure (SOC 10)	Impact on the number of tourists
LUF 3 Cultural	Consumers and households (ECO 7)	Consumers' ability to benefit from the internal market, quality and availability of the goods/services they buy, and on consumer choice, financial situation of individuals / households
	Public authorities (ECO 10)	Budgetary consequences for public authorities
	Macroeconomic environment (ECO 11)	Consequences on conditions for investment and for the proper functioning of markets
	Biodiversity, flora, fauna and landscapes (ENV 6)	Impact on scenic value of protected landscape
	Tourism pressure (SOC 10)	Impact on the number of tourists, types of tourism and the nature areas of the host region
	Landscape identity (SOC 11)	Impact on the continuity of the specificities and the unique character of the areas, the natural heritage, the cultural heritage (artefacts, monuments and also knowledge, know how of land use techniques, of handicrafts, which are characteristic in a landscape giving the identity, the unique sense of place), the level of people's awareness of the heritage, as well as the protection measures, the scenic value of the landscape and environment that is perceived and appreciated by people
LUF 4 Residential and Land independent production	Competitiveness, trade and investment flows (ECO 1)	Impact on the cross-border investment flows (including relocation of economic activity)
	Operating costs and conduct of business (ECO 3)	Impacts on cost or availability of essential inputs (raw materials, machinery, labour, energy, etc.)

LUFs	Impact Issues	Examples
	Innovation and research (ECO 6)	Consequences for research and development, technologies and products
	Consumers and households (ECO 7)	Impacts on financial situation of individuals / households, both immediately and in the long run, economic protection of the family and of children
	Specific regions or sectors (ECO 8)	Effects on construction sector, on certain regions
	Macroeconomic environment (ECO 11)	Consequences of the option for economic growth and employment, conditions for investment and for the proper functioning of markets and inflationary consequences
	The likelihood or scale of environmental risks (ENV 9)	The likelihood of natural disasters
	Landscape identity (SOC 11)	Impact on the continuity of the specificities and the unique character of the areas
LUF 5 Land-based production	Competitiveness, trade and investment flows (ECO 1)	Impact on the competitive position of EU firms in comparison with their non-EU rivals
	Operating costs and conduct of business (ECO 3)	Impacts on cost or availability of essential inputs (raw materials, machinery, labour, energy, etc.)
	Specific regions or sectors (ECO 8)	
	Macroeconomic environment (ECO 11)	Consequences of the option for economic growth and employment
	Water quality and resources (ENV 2)	Effect on the quality or quantity of freshwater and groundwater
	Soil quality and resources (ENV 3)	Affect the acidification, contamination or salinity of soil, and soil erosion rates, usable soil availability (e.g. through building or construction works or through land decontamination)
	The climate (ENV 4)	Changes in the emission of greenhouse gases (e.g. carbon dioxide, methane etc) into the atmosphere
	Waste production, generation and recycling (ENV 8)	Affect waste production (agricultural or mining), waste disposal, or waste recycling

LUFs	Impact Issues	Examples
	The likelihood or scale of environmental risks (ENV 9)	Risk of unauthorised or unintentional dissemination of environmentally alien or genetically modified organisms
	Employment and labour markets (SOC 1)	New job creation or loss, demand for labour and functioning of the labour market
LUF 6 Transport	Operating costs and conduct of business (ECO 3)	Impacts on cost or availability of essential inputs (raw materials, machinery, labour, energy, etc.), access to finance
	Public authorities (ECO 10)	Budgetary consequences for public transport
	Macroeconomic environment (ECO 11)	Consequences of the option for economic growth and employment
	The likelihood or scale of environmental risks (ENV 9)	Impact on the likelihood of explosions, accidents and accidental emissions
	Employment and labour markets (SOC 1)	Demand for labour and functioning of the labour market
	Tourism pressure (SOC 10)	Impact on the infrastructure of the host regions and the nature areas of the host region
LUF 7 Provision of abiotic resources	Macroeconomic environment (ECO 11)	Indirect links related to the level of agricultural and industrial use of land
	Air quality (ENV 1)	Effect on emissions of acidifying, eutrophying, photochemical or harmful air pollutants that lead to deterioration in the environment (polluted soil or rivers etc)
	Water quality and resources (ENV 2)	Effect on the quality of waters in coastal and marine areas (e.g. through discharges of sewage, nutrients, oil, heavy metals, and other pollutants), drinking water resources
	Soil quality and resources (ENV 3)	Affect the acidification, contamination or salinity of soil, and soil erosion rates
	The climate (ENV 4)	Changes in the emission of ozone-depleting substances and greenhouse gases into the atmosphere
	Waste production, generation and recycling (ENV 8)	Affect waste production (solid, urban, agricultural, industrial, mining, radioactive or toxic waste), waste treatment,

LUFs	Impact Issues	Examples
		waste disposal, or waste recycling
LUF 8 Support and provision of biotic resources	Public authorities (ECO 10)	Budgetary consequences for public authorities at different levels of government and establishing new or restructuring existing public authorities
	Macroeconomic environment (ECO 11)	Consequences of the option for economic growth and employment, rising government expenditure and the application of a range of measures - mostly technical - in industry
	Air quality (ENV 1)	Effect on emissions of acidifying, eutrophying, photochemical or harmful air pollutants that lead to deterioration in the habitats
	Water quality and resources (ENV 2)	Effect on the quality or quantity of freshwater and groundwater
	Soil quality and resources (ENV 3)	Affect the acidification, contamination or salinity of soil
	The climate (ENV 4)	Changes in the emission of ozone-depleting substances and greenhouse gases into the atmosphere
	Biodiversity, flora, fauna and landscapes (ENV 6)	Impact on number of species/varieties/races in any area (i.e. reduce biological diversity) or range of species, protected or endangered species or their habitats or ecologically sensitive areas
	The likelihood or scale of environmental risks (ENV 9)	Impact on the risk of unauthorised or unintentional dissemination of environmentally alien or genetically modified organisms
	Tourism pressure (SOC 10)	Impact on the nature areas of the host region
LUF 9 Maintenance of ecosystem processes	Public authorities (ECO 10)	Budgetary consequences for public authorities at different levels of government
	Macroeconomic environment (ECO 11)	The increase in environmental expenditure as a proportion of total government expenditure
	Air quality (ENV 1)	Effect on emissions of acidifying, eutrophying, photochemical or harmful air pollutants that lead to deterioration in the ecosystems
	Water quality and resources (ENV 2)	Effect on the quality or quantity of freshwater and groundwater

LUFs	Impact Issues	Examples
	Soil quality and resources (ENV 3)	Effect the acidification, contamination or salinity of soil
	Biodiversity, flora, fauna and landscapes (ENV 6)	Landscape splitting into smaller areas affecting migration routes
	Waste production, generation and recycling (ENV 8)	Affect waste production (solid, urban, agricultural, industrial, mining, radioactive or toxic waste)
	The likelihood or scale of environmental risks (ENV 9)	Impact on the likelihood or prevention of fire

4 The Land Use Function framework for regional assessment of land use sustainability

The general framework developed in SENSOR for assessment of the impact of a policy scenario (simulated land use changes) on the economic, environmental and societal sustainability of the land use of a region is schematised in Figure 2. It shows the role of the LUFs in the general SENSOR framework

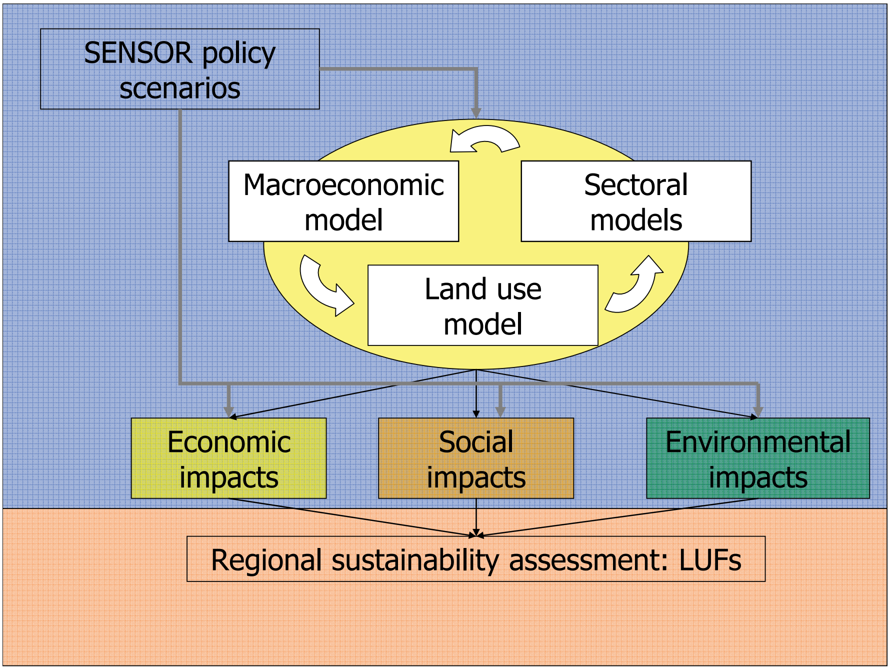


Fig. 2. The general framework for regional impact assessment in SENSOR

The regional scale in the LUF framework is based on a set of 27 cluster regions that cover EU27 + Norway and Switzerland, which are defined according to the relative homogeneity of their bio-physical and socio-economic characteristics of the group of NUTS-X regions that form each of the clusters and are likely to be affected by the SENSOR scenarios i.e. the Spatial Regional Reference Framework (SRRF).

The SRRF is described in detail by Renetzeder et al. (2008), and forms the basis of the regional SIA within SENSOR. The issue of how representative the cluster regions are will be approached in the group and internet valuation in Test Regions and in the regional case studies, supported by the stakeholder consultation exercises.

The detailed implementation of the LUF conceptual framework is schematised in Figure 3.

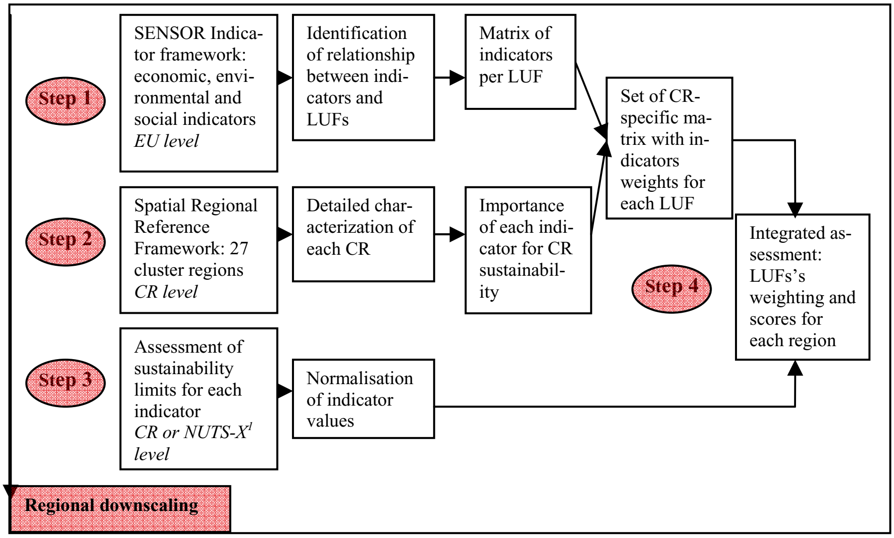


Fig. 3. Methodological approach for integrated Sustainability Impact Assessment at regional level based on the LUFs concept

The following methodological steps, sketched in Figure 3, are identified:

Step 1. Identification of the nature of the relationship between indicators and LUFs: matrix of indicators characterising each LUF

The impacts of land use changes on sustainability are measured in SENSOR by a large set of approximately 40 economic, environmental and societal indicators that are affected by land use and that are expected to provide a picture of sustainability impacts at the regional scale (Farrington et al., 2008; Frederiksen and Kristensen, 2008; Petit et al., 2008). These indicators can be modelled in the model chain providing the results of the policy scenarios. The EU Guideline for Impact Assessment (CEC, 2005) does not mention indicators as the output of the assessment. Therefore SENSOR has developed and used policy-relevant indicator-sets that have been linked to the impact issues highlighted in the EU Guideline for Impact Assessment (CEC, 2005), as mentioned in Table 2. The impact issues - to be screened in relation to a given proposal- cover general policy objectives of the EU and are related to the economic, environmental and social dimensions.

From this extensive list of 40 indicators, a selection was made in a two iterations process by an interdisciplinary expert team consisting of economists, environmentalists, landscape ecologists, geographers, tourism specialists and sociologists. The selection criteria were as follows:

(i) the indicator should present direct or indirect causal links to the LUF;
(ii) indicators should be meaningful at regional level;
(iii) the indicator set per LUF should cover a range of impact issues from the EU guidelines balanced among the three pillar of sustainability;
(iv) redundancy among indicators should be avoided.

The final list of indicators considered in the LUF Framework consists of a reduced set of approximately 25 economic, environmental and social indicators. The predominance of environmental indicators will be compensated by using a weighting system to balance the contribution of indicators to each LUF in the last part of the assessment.

The links between the selected indicators (called from now on *key impact indicators*) and the LUFs are generic for all the cluster regions, i.e. there is no difference between the cluster regions in the set of indicators that characterise a single LUF, and therefore the links are the same at EU level. The relationship between indicators and LUFs is multilateral (n:n), i.e. on one hand, each LUF has a different number of indicators per sustainability pillar; on the other hand, one indicator may characterise several LUFs in different ways, sometimes across several pillars. For example, NH_3 emissions may affect four LUFs i.e. human health and recreation (LUF2- social), provision of abiotic resources (LUF7- environmental), support and provision of habitat (LUF8-environmental) and maintenance of ecosystem processes (LUF9-environmental). The fact that one environmental indicator has links not only with the mainly environmental LUFs but also with a social LUF, shows the strength but also the complexity of the interactions in this sustainability assessment framework.

The links show how each *key impact indicator* influences each LUF i.e. the nature of their relationship. The indicators address the economic, environmental and social main contextual characteristics of the regions. The indicator values can favour (or hinder) the performances of the LUFs. Thus, they help in examining the overall potentials of the LUFs on the base of the assumption that 'good' economic, environmental and social conditions mean high potentials in terms of LUFs. For example, emissions of NH_3 from agriculture may have a potential negative impact on the quality of air, water and soil, and consequently NH_3 emission may potentially hinder the land use function defined as provision of abiotic resources (LUF 7). Links are documented in a generic table that includes all the indicators characterising each LUF. Table 3 provides an example for NH_3, one of the indicators linked to LUF7, presenting the scores associated to the contribution as well as the justification and the confidence on the scoring in each column as follows:

(i) *Name of the indicator*;

(ii) *Impact issue*, i.e. which sustainability impact issue is tackled;

(iii) *Score for link with LUF*, i.e. the strength of the significance of each indicator for the LUF, using weighing scores ranging from -2 to +2 as follows:

- 2 = strong significance i.e. the indicator hinders (-) or enhances (+) the function in a very significant way. For example, the indicator 'Labour productivity' has a strong negative link with LUF 1 Provision of work, because an increase in labour productivity means the economy needs less workforce;
- 1= medium significance, i.e. (a) the indicator hinders (-) or enhances (+) the function but in a limited way. For example, the indicator 'Energy cost' has a medium negative link with LUF 2 2 Human health and recreation, because in case of increase of energy cost, short distance recreation activities will be privileged, to the prejudice of more distant destinations;
- 0 = irrelevant, i.e. the relationship between the indicator and the LUF does not allow one to infer on the consequences that a change in the indicator value could have on the LUF. For example, the indicator 'Trends in farmland birds' is irrelevant for the LUF 6 Transport;

(iv) *Justification for score*, i.e. the criteria used by the experts are provided in a column 'justification for score', which also includes scientific references;

(v) *Confidence of expertise*, i.e. an indication of the confidence of the expertise on the scoring is given in the last column of the generic table (high, medium or low).

Table 3. Example of generic table for the indicator NH_3 affecting LUF 7 (provision of abiotic resources)

LUF7: Provision of abiotic resources

Indicator	**Impact issue**	**Score for Link with LUF**	**Justification for score**	**Confidence of expertise**
NH3	ENV 1 (Air Quality)	-2	Ammonia emissions affect negatively the quality of air, water and soil. Ammonia is a secondary particulate precursor affecting air quality. It can cause plant damage. In addition, deposition of nitrogen compounds from NH3 emissions can lead to increased concentrations of nitrate in ground and drinking water due to nitrate leaching. Finally, ammonia emissions increase the N deposition and can lead to eutrophication and acidification of soils (EEA 2001; Oenema et al. 2007).	High

Table 4 shows an imaginary generic table, which summarises the cross-linkages between the key impact indicators and the nine LUFs.

Table 4. Example of generic table summarising cross-linkages between key impact indicators and LUFs

	LUF1	**LUF2**	**LUF3…**	**LUF9**
Indicator 1	-1	1	0	1
Indicator 2	1	0	0	1
Indicator 3	-2	1	-1	0
Indicator 4…	-1	-1	1	0
Indicator n	0	0	2	2

The advantage of using a generic table is that it makes it easier for independent experts to assess the links. The difference between regions is addressed by varying the importance of each key indicator through weighting in step 2.

Step 2. Identification of the importance (weighting) of each key impact indicator for the sustainability of the regions

This step provides the regional dimension to the framework by evaluating for each region the potential importance that each key impact indicator may have on the land use sustainability. The regional assessment is made in SENSOR for each cluster region of the SRRF. The evaluation of the importance is done by using cluster-specific information obtained from 'Detailed description of Cluster Regions for supporting Regional Sustainability Assessment' (Bunce et al. 2007). The detailed description is not exhaustive and therefore for some indicators other sources explicitly concerning the impact of the indicator have been used.

It is well accepted that changes in indicators - that is measurements of something in the economy, environment or society – may be of different importance in relation to our efforts to assess the changes in phenomena (such as land use). In other words, it means that some 'things' are more important for the phenomena we are concerned than others. Therefore, weighting of different indicators is a normal procedure in Environmental Assessment and Strategic Environmental Assessment, and indeed finds its place in EU Impact Assessment. However, agreeing on the weighting is difficult. It can be imposed 'top-down' by policy makers/administrators and their advisory scientists, or generated 'bottom-up' by stakeholders. Ideally, one might have different weighting systems derived from different sources such as expert ('Delphi') panels, stakeholder valuation workshops, internet valuation, etc. and present them in final outcomes to assess the risk. At this stage of the project, we have chosen to limit ourselves to expert panels. At a later stage of the project, the 'expert' results will be presented, discussed and valuated in stakeholder workshops.

The description of the decision rules used by the experts is transparently done in individual fact-sheets, which include the 'importance' weighting showing how significant an indicator (impact issue) is in that region (see Textbox 1). It is an expert-based value judgement on what impact it would have on sustainability in the region if that indicator was to have an unacceptable value based on the current knowledge.

The criteria used for the weighting are scientifically robust and are shown in a table using the following ranking: 0 = indicator is not relevant to assess sustainability in the region; 1 = indicator has some importance for the sustainability of the region; 2 = indicator is important for the sustainability of the region. In addition, literature references are provided. In case data gaps were found, a symbol was used for missing data.

Textbox 1: Example of fact sheet for NOx, showing the description of the decision rules provided by the experts

ENV1.1 Nitrogen oxides
Laurence Jones, NERC

Nitrogen oxides (NOx) can have impacts on human health (respiratory problems), can damage buildings and crops via acid rain, and is one source of atmospheric nitrogen (the other major source is ammonia) which when deposited can lead to eutrophication of natural habitats. Thus its importance was calculated based on a combination of population density in a cluster (for human health and impacts on the built environment) and the proportion of habitats potentially sensitive to eutrophication – which was taken to include all land protected under NATURA 2000 designation (or similar data from CORINE Biotopes for those countries for which NATURA data were not available). Population density was obtained from the detailed description of cluster regions, taken as the upper limit of the range in which the median population density occurred (median of the distribution of values for all NUTSx regions in that cluster). The proportion of land under NATURA 2000 or similar designation was also calculated per Cluster region. The basic rules for attributing a score in relation to these two descriptors were as follows:

- Population density:

IF Pop Dens < 50 THEN score 0
IF Pop Den 50 < x < 100 THEN score 1
IF Pop Dens > 100, score 2

- Proportion of protected land area:

IF Prot Area < 0.25 THEN score 0
IF Pop Den 0.25 < x < 1.75 THEN score 1
IF Pop Dens > 1.75 THEN score 2

Most clusters have reasonably high population density somewhere within the region where NOx effects may occur, and all clusters will have some measure of sensitive natural habitats that should be protected from eutrophication. Therefore, these two scores were put together with a simple rule base to achieve a final score which is intended to highlight the importance of NOx in all regions except those which really have very few centres of population or have very little habitat in need of protection from eutrophication. The rule base for calculating the final importance for NOx in each cluster was as follows:

If scores sum to 0, score 0
If scores sum to 1, score 1
If scores sum to 2 or more, score 2

The result of the implementation of the indicator 'importance' criteria gives finally how many and which indicators make up a LUF for a certain region, i.e. the 'aggregate functionality'. This means that a LUF might be made up of different indicators depending on the region i.e. the significance of indicator values in LUFs varies at regional level. Table 5 shows an example of how the regional dimension is considered in the assessment.

Table 5. Example of a table summarising the assessment of the importance (weight) of the indicators in each cluster region (CR)

	CR1	CR2	CR3…	CR27
Indicator 1	1	0	1	2
Indicator 2	1	2	0	0
Indicator 3	2	0	1	1
Indicator 4…	0	1	0	1
Indicator n	1	0	2	0

Table 6. Specific tables for each of the 27 Cluster Regions (CR), listing the key impact indicators relevant in the region and their individual contribution to the LUFs.

	LUF1	LUF2	LUF3…	LUF9
Indicator 1	-1	1	0	1
Indicator 2	1	0	0	1
Indicator 3	-2	1	-1	0
Indicator 4…	-1	-1	1	0
Indicator n	0	0	2	2

	CR1
Indicator 1	1
Indicator 2	1
Indicator 3	2
Indicator 4…	0
Indicator n	1

CR1	LUF1	LUF2	LUF3…	LUF9
Indicator 1	-1	1	0	1
Indicator 2	1	0	0	1
Indicator 3	-4	2	-2	0
Indicator 4…	0	0	0	0
Indicator n	0	0	2	2

The combination of the generic table (step 1) and the assessment of the importance of the indicators enable the development for each cluster region of a *specific regional table* which provides an overview of the indicators with a relevant impact on the LUFs (with their weight) for that specific region (Table 6). The regional dimension is applied by multiplying weights from step 1 (generic table) with step 2 (importance in the cluster region). This step follows a previous (hidden) step of balancing indicators to LUFs by weighting, based on the final number of indicators that set up a LUF in each specific cluster region.

Step 3. Assessment of sustainability limits for the regions and normalisation of indicator values

The third step in the assessment process is the expert identification of regional specific 'sustainability limits' (thresholds or similar references) for each indicator and the normalisation of the indicator values.

Sustainability limits are defined as the unacceptable damage of a pressure on a social, economic or environmental system based on current knowledge. The analytical background for this approach is further described by Bertrand et al. (2008). The sustainability limits are scientifically sound and spatially explicit, and refer to the impact of the key indicators on each LUF and for each region considered (for each NUTS-X region).The rationales for identification of the sustainability limits are based (i) on policy targets, (ii) on statistical distributions of indicator current values, or (iii) on scientific values. They can be quantitative (e.g. policy target that the European average is the optimum level –target- to achieve; or qualitative (e.g. forest fire risk = Low, Medium, High). Values provided as sustainability limits are soundly based, traceable and scientifically justified.

The assessment of sustainability limits has proved to be challenging concerning mainly two issues. Firstly, it is difficult to derive limits for socio-economic indicators in the same way as for environmental indicators. We can estimate quite correctly which level of nitrate in water supply might be toxic, but it is more complex to define at what point a ratio of tourists to local inhabitants threatens the sustainability of local nature, culture, history, etc. Secondly, there is a large heterogeneity in the European territory that makes it difficult to define accurately regional limits based on the current data availability.

Normalisation of all indicators to the same scale is required in order to compare the different indicator units and values and therefore apply the weightings used in the LUFs framework. The normalisation methods, which are described in detail by Paracchini et al. (2008), may differ between indicators in order to accommodate both (semi-)qualitative, e.g. net migration, and varying forms of quantitative indicators, e.g. N and P surplus. For the purpose of calculations in this framework the scale is defined from -3 (least sustainable) to +3 (most sustainable) where 0 represents the sustainability limit (if appropriate). The scale is continuous where possible rather than discrete, but for some indicators where this is not possible, the normalised scale can take discrete values, as for example with semi-qualitative indicators such as Forest Fire Risk. The normalisation method is designed such that the scale is divided according to equal units of impact on 'sustainability', i.e. a change in one normalised indicator score from +2 to +2.5 has the same meaning in terms of sustainability as for any other indicator. Indicator values are therefore converted to a normalised scale which denotes whether they are above or below an acceptable value for sustainability.

Once that the indicator values are normalised, it is possible to compare the analysed quantitative and qualitative changes in key impact indicators provided by the SENSOR model-chain for the different policy scenarios, with the respective sustainability limits. If the indicator value is below the limit, then we will assume that the performance of the function linked to the indicator will not be affected. On the contrary, if the limit has been exceeded for a specific indicator, its contribution to the function will be changed. As a result, the effect of a policy on the land use sustainability of a region will be described by the changes caused in its LUFs, which is a comprehensive and integrated description of changes observed in each single indicator. For example, if the predicted value of N surplus for a region is 60 kg N/ha y^{-1} which is above the sustainability limit of 50 kg N/ha y^{-1}, then the performance of the LUFs linked to this indicator will be affected - in this specific case hindered - i.e. provision of abiotic resources, support and provision of biotic resources and maintenance of ecosystem processes.

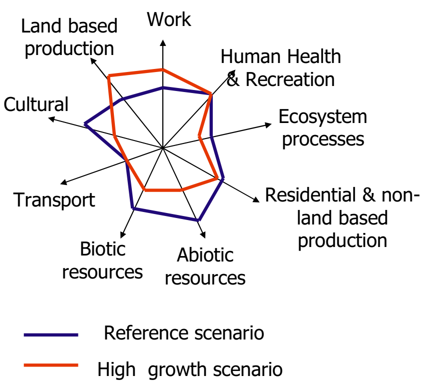
Step 4. Integrated assessment of the effect of a policy scenario on the sustainability of the land use in a region

The final step is the integrated assessment of the impact of a policy option on the sustainability of the land use of a region. It is based on the summary output for each LUF provided in steps 1, 2 and 3. The integrated weighing of all the indicator values (methodology is described by Paracchini et al. 2008), which limits have been exceeded or not provides a comprehensive description of changes observed in the key indicators, which show the overall consequences (stimulating, hindering or none) for the LUF. This step allows us to tackle the multifunctionality associated with sustainability issue. They provide a targeted input to the Sustainability Choice Space framework, which describes the degree to which alternative policy outcomes are acceptable to stakeholders across a range of criteria i.e. explore and visualise what 'room for manoeuvre' policy makers might have in the design of a specific policy. This concept is described by Potschin and Haines-Young (2008).

The final assessment has two parallel aspects: (i) assessing change in indicator values, which provides more detailed information about how a policy affects regions; 2) assessing the number of indicators in an unacceptable condition (e.g. not reaching target, or exceeding threshold), which takes into account the indicator score relative to a threshold/target where appropriate. Resulting scores are compared with a potential score for that region, to allow comparability between regions.

Textbox 2. Example for the bio-energy policy case

- Scenario: Higher demand in biofuel crops (rapeseed, sunflower, sugar beet, etc.)
- Policy variables: subsidies for producing biofuel crops
- Model chain analyses the complex inter-relations of economic, environmental and societal variables and produces the following (summarised) main changes:
  - Land use: lower rate of abandonment of arable land with national restrictions
  - Changes in indicators due to the impact of the high growth scenario when compared with the reference scenario :
    - Increase in fuel (cultivation and harvesting), fertilizer and water consumption
    - Increase in eutrophication
    - Decrease in erosion and soil compaction
    - Reduced biodiversity
    - Decrease in GHG emissions
    - Increase in employment in rural areas
- The impact of the policy scenario on land use sustainability are summarised in the changes in the nine LUFs, shown in the figure below



5 Discussion

Following the SIA need for true integration of economic, environmental and societal issues across policy areas at a meaningful spatial scale (CEC, 2005; CEU, 2006), SENSOR is developing an innovative conceptual framework to assess the impact of simulated policies on the sustainability of land use at various levels of spatial aggregation (from cluster regions to NUTS 2/3 administrative units). This new SIA tool integrates the changes observed in a large set of key impact indicators into nine functions of the land used (LUFs), which are modified by those indicators. In other words, it helps to identify those functions which are hindered (usually the functions associated with non-market benefits) or enhanced, and accordingly to find ways for their adequate compensation and stimulation of efficient resource allocation at the territorial scale, which are basic principles of sustainable development. In the LUF framework, land use multifunctionality is considered therefore in a territorial rather than in a sectoral context.

The three main advantages of the LUF framework are as follows:

(i) it simplifies the classic complex impact assessment based on a large number of indicators by grouping the indicators into land use functions (fig 4), and therefore makes it possible to identify at a glance those functions of the land which use are hindered and those functions which are enhanced by a policy option;

(ii) it makes explicit the connection between multifunctionality and sustainable development. We consider multifunctionality through the multiple functions that the use of land may have in a specific geographical region concerning the social expectations and requirements. The LUFs framework interlinks the functions of the land mainly characterized by the production of market goods and services with the mainly non-market functions and illustrates their trade-offs and therefore raises the question of the implications of multifunctionality for the sustainability of the region;

(iii) it supports the definition of societal objectives of sustainable development at various levels of spatial aggregation by providing a *modus operandi* and more appealing basis for assessing multiple stakeholder preferences for future changes and for presenting the impact of policies to regional stakeholders.

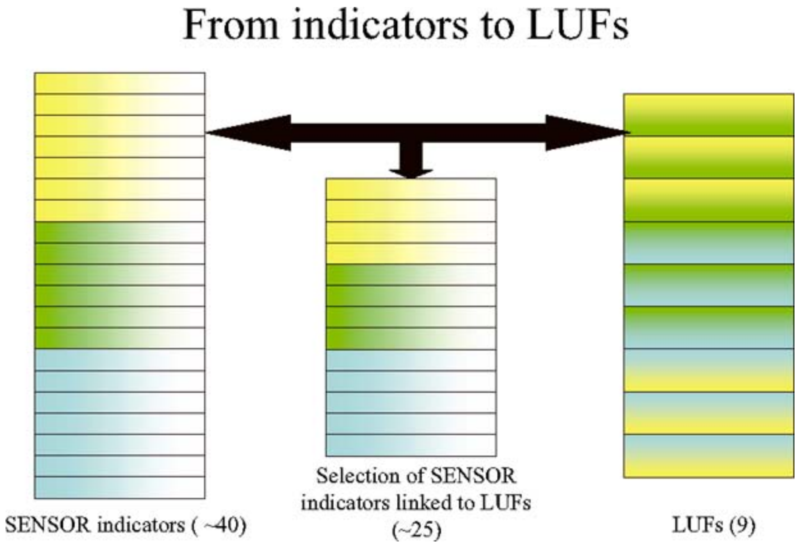


Fig. 4. The LUF concept simplifies the classic complex Impact Assessment based on a large number of indicators, by grouping the indicators into nine land use functions.

There is a test for the LUFs methodology that we still need to perform. Are we confident that the chosen combination of indicators in the LUFs will actually produce results that are 'correct' in our expert opinion? In other module of the project we review the regional results for LUFs against expert understanding and expectations of the local stakeholders (methodology described by Morris, 2008). Based on preliminary results of the stakeholder valuation workshops we conclude that set of indicators defining the impact on the LUFs may vary in each SIA depending on the regional or local context of the assessment. This last phase in the LUF methodology is supported by the concept of a 'Sustainability Choice Space' that represents the step from interdisciplinary to transdisciplinary approach, showing that participative research involving stakeholders who are not academics has been done (Winder, 2003). This final stage will be documented and explained in the SIAT Users Manual.

In conclusion, the LUF framework makes explicit the analytical links between multifunctional land use and sustainable development, and therefore allows us to look at multifunctionality as a way towards sustainability. Moreover, it sets up the path to identify the conditions required to preserve the social cohesion and economic and natural environment continuity beyond the present generation. Ultimately, it allows assessment of the multiple stakeholder preferences for LUFs and provides policy makers, scientists and stakeholders with a new tool for regional SIA of land use changes.

Finally, and most importantly, policy making is a complex process. Following the presented framework, decision-makers will weight up the implications of a new policy, plan or program on the LUFs in the wider context of their own interests and those of their citizens. The LUF methodology will not make the final decision. It will simply inform it.

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Limits and targets for a regional sustainability assessment: an interdisciplinary exploration of the threshold concept

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Abstract

Some encompassing terminology is required in order to accommodate different conceptual approaches in the three pillars of sustainability. So, this chapter provides a literature review exploring the threshold concept. In environmental research – especially in ecology – thresholds are often associated with limits which have certain system-inherent processes. In social and economic disciplines, if the notion of limit or critical limit is present, the concept of *targets* is often more appropriate which are linked to political objectives and social acceptability. The concept of threshold is accommodated within the general framework of limits and targets. What is important is the understanding developed here that almost any environmental, social or economic system has the potential to reach a point or an area that is unsustainable, or outside acceptable limits, relevant at a regional level.

When identifying values for limits, a number of issues need to be considered. The consequences of exceedance of limits depend to a large extent on two related concepts, more or less relevant for both environmental and socio-economic sciences: path dependency and reversibility. Together,

these help understand what the socio-economic and environmental consequences are, if they are reversible and the likely cost of achieving reversibility, or whether exceedance precludes any recovery. Exceedance of environmental limits often has a direct cost, revealed across many sectors, whereas the costs associated with exceedance of socio-economic limits may be harder to quantify. Together with a concept of risk, these concepts lead us to apply the precautionary principle, in other words to set conservative limits that define 'unacceptable consequences' some distance in advance of the point (or area) at which system break down or severe damage occurs. Crucially, these limits are derived through deliberative processes and involve both social acceptability and political input, together with scientific understanding of how the system operates (be it socio-economic or environmental).

Firstly, the paper explores the concepts of targets and limits from environmental and socio-economic perspectives and suggests some unifying terminology. Secondly, we examine some of the issues of uncertainty in considering values for limits or targets. These issues deal with the notion of equilibrium, the understanding of complex processes and the capacity of a system to adapt to an external event. Thirdly we underline how this uncertainty in the regional assessment challenges our ability to predict the consequences of exceeding the limits.

Keywords

threshold, target, limit, sustainability assessment, region, environment, socio-economy

1 Introduction: Defining a common objective for an interdisciplinary sustainability analysis

The rapid rate of land use change today has impacts on both environmental and socio-economic systems. Interdisciplinary research which is supposed to integrate these dimensions, encounters various issues including issues of spatial and temporal scale, and especially issues concerning common approaches to analysis. The integrated project SENSOR provides the opportunity for a regional sustainability assessment through the concept of regional thresholds. Indeed, the concept of threshold is used in SENSOR as a crucial component required to perform a regional sustainability impact assessment to support decision making on policies related to multifunctional land use in European regions. The challenge is to incorporate different social, economic and environmental ideas of thresholds and limits into one unified approach without compromising the underlying principles behind these concepts.

Several concepts of threshold arise from the processes studied, and notions such as equilibrium disturbance, breakpoint or area of change are commonly challenged for the three pillars of sustainability by: environmental, social and economic frameworks. In dealing with discontinuities in processes or change of regime (Matias et al., 2006), there are however differences in the way environmental and socio-economic sciences understand the concept. Through a literature review on theories involving thresholds in environmental and socio-economical studies, this chapter describes the ways boundaries of sustainability can be perceived in each discipline and how a synthesis of these ideas leads to the notions of limits and targets as a conceptual framework to set the boundaries of sustainability. The final objective of this chapter is to revisit the concept of threshold to provide the scope for the SENSOR regional sustainability assessment.

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2 An exploration of the concept of thresholds through limits and targets.

The idea of threshold has been recognised by ecology and ecological economists as a key concept to study changes in ecological processes and non-linear modelled economy-environment interactions (Muradian, 2001). However, definitions and understanding of the 'threshold' concept differ between environmental and socio-economic disciplines. In ecology, there is a large body of literature discussing thresholds, also called discontinuities, (reviewed in Folke et al., 2004; Huggett, 2005; Muradian, 2001; Scheffer et al., 2001), where the simplest definition of a threshold is: a rapid state change occurring as a consequence of smooth and continuous change in an independent variable (Luck, 2005; Muradian, 2001). Economic approaches based on the idea of equilibrium deal with discontinuities in the evolution of variables over time e.g. standard economic growth models or classical theory of localisation. In environmental economics, the concept can be related to an *optimum value* (e.g. cost/benefit to society) linked to social preference, pressure, market context or even policy decision, but also to the idea of substitutability between human and natural capital, which is discussed further below (footnote 1). In sociology, the term *threshold* is rarely used; although it does feature in some sociological models, like critical mass models.

2.1 Thresholds as discontinuities in processes

Thresholds or discontinuities refer to system change, linked to the notions of equilibrium disturbance, breakpoints or areas of rapid change in a system. In environmental systems, simple thresholds can be represented so that increasing pressure such as a pollutant load leads to exceedance of a threshold (Figure 1a at point A), beyond which point there is a drastic increase in damage, e.g. a loss of biodiversity. A thorough example of a lower limit threshold shown to operate in landscape ecology is detailed in Radford et al. (2005) who detected a limit of 10 % woodland cover required for woodland birds in a fragmented landscape in southern Australia. Below this level of woodland cover, species richness declined dramatically, while above this level, there was little change in species richness. Such empirical observations can be tested in modelling studies, e.g. modelling of fragmentation thresholds was reviewed by Andren (1994) who suggests that fragmentation thresholds typically occur where 10 – 30 % of suitable habitat remains.

The threshold concept has attracted much interest in ecological systems in the catastrophic switching between alternative stable states. These switches can arise in natural systems where a given set of conditions can result in multiple alternative states, as shown in population ecology models of predator-prey abundance (May, 1977). The catastrophic shift between stable states is illustrated schematically in Figure 1b. Up until point A_1, an increase in the pressure results in a more or less linear response in the response variable. However, at point A_1, a sudden shift occurs to a new state, at A_2. One example from marine systems is the influence of sea otters on inter-tidal kelp beds. With an abundant sea otter population, there is high macrophyte productivity, high density of fish and harbour seals, and low invertebrate density. However, a decline in sea otters through hunting causes a shift to an alternative state in which the conditions are reversed (Estes and Palmisano, 1974). Here the limits can be interpreted as the point at which a desirable state shifts to an undesirable state or at which one state shifts to another.

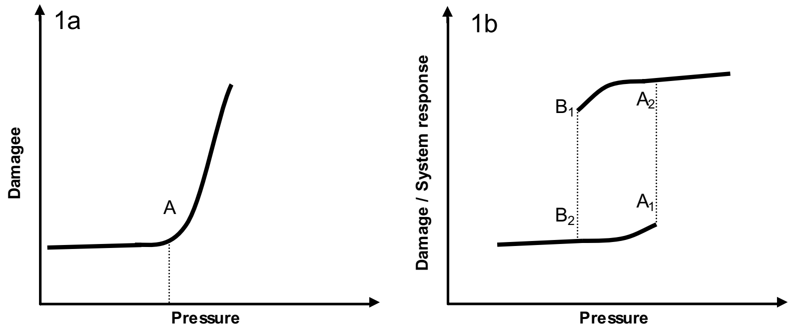

Fig. 1. Diagrams illustrating some general concepts of thresholds, relevant primarily to environmental systems, but also to some social and economic systems. 1a shows a simple threshold or breakpoint; 1b shows alternative stable states with the switch points occurring at system thresholds A_1 and B_1.

The idea of breakpoints or areas of rapid change is present also in economics in the context of equilibrium disturbance in the balance between benefits and costs in commercial exchanges. In spatial economics studies (i.e. Polèse and Shearmur, 2005) the concept was developed in relation to spatial concentrations of people. Also, in urban economics, through the question of cities' size and city expansion, the notion of threshold was used as an *optimum value* between human cost of urban concentration and benefits linked to agglomeration externalities for businesses (Catin, 1991; Paelink and Sallez, 1983; Parr, 2002). A similar concept has been used in the assessment of congestion effect of land use in agricultural activity (Bonnieux and Rainelli, 2000; Dupraz, 1996). In this case, the analysis of management practices and expenditure justification of agricultural production refers to thresholds as a point or area of change in which production of goods is substituted by an increase of positive/negative externalities (here congestion effect of land use). Threshold - as "critical" limit - expresses this relation of substitutability between environmental/rural amenities (positive externalities) supply and commodity outputs.

Finally, the use of threshold in a land use perspective can be strongly linked to ecological economic analysis, associating a value at which a good (or a service) provided to society changes or is considered to be maintained by society. However, the debate is open on the neoclassical utility theory which assumes that all values are commensurable and ultimately reducible to a single metric of economic welfare[1] (Malinvaud, 1972; Varian, 1992). Indeed, decision processes regarding choices on environmental issues are considered by other authors as non-compensatory, based on value hierarchies depending on ethics, behaviours, context, priorities between environmental and non-environmental goods and services. The notion of *lexicographic preferences* is used to express "a general unwillingness to trade or accept compensation for changes in an environmental good" (Spash, 2000). These preferences in environmental valuation overrule the assumption of continuously defined, differentiable preferences linked to standard neoclassical theory (Rosenberger et al., 2003). Two forms of lexicographic preferences are distinguished (Lockwood, 1996): a "strict" preference for which goods in any quantity or quality are always preferred over all quantities or qualities of other goods, and a more adaptable preference ("modified lexicographic preferences") based on thresholds (Lockwood, 1996). These thresholds correspond "*to minimum levels of a good that are necessary and prior to choice for other goods*" (Rosenberger et al., 2003)

2.2 Continuity in processes and non-threshold relationships: the notion of social and political targets

In reality, the exploration of non threshold relationships shows that most analyses of social and economic systems and also many relationships in ecology are not based on thresholds. The complexity of processes and re-

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[1] Two extreme positions exist here however. The first ones are stronger positions (represented by Georgescu-Roegen, 1971) asserting that many natural ecological functions are irreplaceable and that any substitution is impossible. So, studies focused on ecosystem limits as a potential guide for management decisions, argue for stability in the ecological services provided by ecological systems (Muradian, 2001). In this case, economic threshold is defined as the period or a point at which the net income from cropping is reduced according to these ecosystem limits. Broader developments on thresholds are made in sustainability economics related to the idea of potential substitutability between man-made capital and natural capital (neoclassical positions represented by e.g. Solow (1992)) arguing that man-made capital can replace all natural capital, except for unique goods. Ayres (2006) argues that, while there is considerable scope for substitution in some domains, the limits to substitutability in the medium term at least are real and important. In this context, thresholds are so defined as at the point or area of substitutability.

gional dynamics, of links between drivers and "receptors"[2] make the definition of discontinuities difficult. This complexity in the analysis of processes is reinforced by the spatial scales and time dimensions involved.

Non-threshold relationships also apply in environmental systems. Simple linear relationships exist, for example an increase in the impervious area of a catchment through infrastructure development (soil-sealing) has been associated with an approximately linear decline in species diversity (Arnold and Gibbons, 1996). Relationships in ecology are based on complex links between living organisms and the physical and chemical conditions and processes within their environment. Therefore, the nature of the response being studied depends on both the scale at which it is studied and the range of the response gradient over which it is being assessed. Composite indicators, by their nature, are formed from the sum of the underlying responses, which frequently operate along the full range of the gradient. Thus, the resulting relationship may not exhibit a clear threshold. In a review of extinction thresholds for saproxylic (those dependent on dead wood) organisms, Ranius and Fahrig (2006) were able to tabulate proposed thresholds for a wide range of individual species studied, from woodpeckers to beetles, but could find no evidence of clear thresholds in studies analysing composite measures of species richness.

A broader overview of economic topics shows that most of the analyses are not based on thresholds, especially in the specific field of regional sustainable development. Far from a "simple" notion of growth, the complexity of development processes and regional dynamics involves different dimensions and different spatial and temporal scales. Regional analysis introduces a new scale of explanation for costs/benefits of a spatial localisation involving spatial division of work (Aydalot, 1984), rationale of decision processes and individual behaviours of localisation (Scott, 2001; Storper, 1997), and the importance of institutions in dynamic processes (Marshall, 1906; Becattini, 1992; Benko and Lipietz, 1992).

If limits are identified, scientifically based or not, they refer often more to social preferences and political objectives, which are better referred to as targets. Targets represent a desired endpoint on a relationship curve, whether that curve is linear or exhibits clear thresholds. Targets have been used in ecology, for example in relation to national Biodiversity Action Plans[3]. In the International Convention on Biological Diversity (CBD) a

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[2] Even if the term is less appropriate for social and economic analysis, these comments are relevant for all three approaches.

[3] For an example from the UK, see http://www.ukbap.org.uk/GenPageText.aspx?id=98

range of environmental targets has been defined[4] some of which are based on a numerically defined target (e.g. Target 1.1: At least 10% of each of the world's ecological regions effectively conserved), while others are based on improvement relative to a current position (e.g. Target 5.1: Rate of loss and degradation of natural habitats decreased). From the economic and social perspectives and concerning regional development at the European scale, targets are clearly identified in the European Union as: political goals and norms for a sustainable European development. These refer also to a specific vision (or model) of European polycentric spatial development (ESDP, 1999) to achieve two policy goals: making the EU economically more competitive in the global market (according to regional concurrence and attractiveness), more socially and spatially cohesive and equitable (Third Cohesion report, 2004; Lisbon Agenda, 2000 and Göteborg Agenda, 2001).

In both socio-economic systems and environmental systems, targets can be more complex with an optimum at a specific value, and sub-optimal conditions on either side. In the environment, such relationships expressing the full range of optimum and sub-optimum conditions are often represented as bell-shaped curves. For example, abundance curves for individual species along an environmental gradient which often follow a Gaussian distribution, or composite responses such as the species richness curve along a fertility gradient described by Grime (1973). In socio-economics, such policy targets exist for addressing social inequality, and are measured in units of deviation from the EU average level.

Thus, as is evident from the different conceptual approaches outlined above, a key challenge is how to accommodate these different conceptual frameworks into one workable system, ***limits*** based on established threshold relationships or breakpoints –or areas of sudden change which define the point beyond which unacceptable consequences are likely to occur, and ***targets*** referring to political objectives or social preferences, which define the aspirational goals towards which we strive in order to achieve sustainability.

3 Issues of uncertainty to consider when defining values for Limits and Targets

A main dimension of sustainability assessment is in identifying and deciding on values for limits and targets. Two main purposes are to assess how

[4] See http://www.biodiv.org/2010-target/goals-targets.shtml

their potential exceedance affects sustainable use of land and how limits' values can be used to set the boundaries for regional sustainability. The concept of a narrowly defined threshold is subject to uncertainty, giving rise to a "critical area". This is true in the life sciences and for some economic and social analyses (Steyer and Zimmermann, 1998).

Indeed, there is always some uncertainty in the underlying data used to define a process or a relationship. However, limits are usually developed on the processes that are best understood, using the most comprehensive data sets and information available. Therefore uncertainty at this level is less of a problem than later on in the process of using and applying limits, as long as the areas of uncertainty are recognised and documented. The main dimensions in the issue of uncertainty are outlined here, especially with regard to the level of understanding and knowledge that we have on any relationship or process.

What are the factors of uncertainty in determining an indicator value in terms of limit and target? Does this uncertainty jeopardise the assessment? The following topics relevant to the environment but also to economic and social indicators acknowledge some of the uncertainties and related issues (resilience, path dependency, reversibility, vulnerability) that need to be taken into account when defining the limit values to be used in the assessment.

3.1 Equilibria and indifference curve in economic limits valuation

A wide-ranging debate is open in economics on process equilibria (and thus on limit values). It opposes classical and neo-classical approaches for which a general stability is established in a context of perfect competitive market (based on rational behaviours and commercial exchanges); to heterodox approaches criticising, in complex systems, establishment of a single equilibrium. This general debate has however relevance to limits' value definition, especially for "critical limits". Two examples can be underlined here to illustrate this.

A set of studies and models concerns dynamics of growth among the poor and of self reinforcing patterns of chronic or persistent poverty (Barrett and Swallow, 2006). The standard economic growth model assumes implicitly that there is a single dynamic equilibrium and hence convergence of all growth paths toward a single level of welfare. If the curve lies above the dynamic equilibrium (limit) there is growth, if the curve lies below the dynamic equilibrium there is decline. However, the recent United Nations Millennium Project Task Force (UNMP, 2005) recommends another conceptualisation of persistent poverty based on the notion of "poverty traps" which depends on the existence of multiple dynamics of equilibria: „The evolution of well-being over time then depends on where one sits relative to the critical thresholds(s) at which the growth function bifurcates" (Barrett and Swallow, 2006, p.4). Another example is illustrative of the difficulty in defining a limit within equilibrium. From a neoclassical welfare economic point of view society can, according to „indifference curves", have the same welfare or wellbeing level with different combinations of goods and services. Based on these considerations the same level of economic welfare can be produced by different combinations of marketed and non-marketed goods, and from an economic point of view, thresholds are therefore hard to find.

3.2 Understanding of complex processes, social acceptability

A degree of uncertainty often exists in our level of understanding of the relationship between the driver and the receptor, or the underlying processes. In environmental systems, it is common that the consequences of limit exceedance are much better understood than the mechanisms leading to limit exceedance, or the precise definition of where the limit lies (Huggett, 2005). In the case of the switch of a lake from turbid to clear conditions, some of the mechanisms which cause the switch and the impact on the lake ecology are well studied, but the precise value of the nutrient concentration at which the switch occurs is difficult to predict (Donabaum et al., 1999). Similar principles apply in socio-economics. The level of complexity and inter-connection between factors in a development process, or socio-economic use of land is so high that in most cases the identification of a value for an indicator limit is beset with uncertainty.

A good example is given in environmental economics referring to the evaluation of demand based on the aggregation of individual preferences. Uncertainty can arise as to social preferences, but also due to the wide range of methods available for evaluation of the willingness to pay to maintain (or have access to) the good or the service involved: e.g. hedonic pricing (Le Goffe, 2000), travel cost methods (Desaigues and Point, 1993); stated preference methods including contingent valuation (Amigues et al., 1996). While these valuation techniques reveal the preferences for individuals, the values obtained by other methods are based on the preferences of political bodies, experts and stakeholders, e.g. the DELPHI method

(Navrud and Pruckner, 1997); multi-criteria methods (Wenstop and Carlsen, 1988)[5].

3.3 Limits with respect to vulnerability and adaptive capacity of systems

In setting limits, we have to take into account the potential impact of its exceedance, and hence the vulnerability (or sensitivity) *vs.* resilience of the system studied. This can be seen as an adaptive capacity and a degree to which a dynamic process is susceptible to, or unable to cope with, adverse effects of pressures. An important property of limits is the vulnerability of the system studied and the idea of increasing risk as the Limit is approached.

As an example, a pressure to which vulnerability assessments are frequently applied is climate change, including climate variability and extreme weather phenomena. Thus, the IPCC Third Assessment Report (TAR) describes vulnerability as "*The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity*" (IPCC, 2001)[6]. Vulnerability is therefore an integrated measure of the potential to respond to change. As such, it incorporates features of environmental systems (ecosystem services), but they are integrated within the socio-economic context of a region or country over time.

In socio-economics, what is in balance is the ability of populations to cope with exposure to certain pressures. So, vulnerability has been specifically defined in the field of food security as "*an aggregate measure for a given population or region of the risk of exposure to food insecurity and the ability of the population to cope with the consequence of the insecurity*" (Downing, 1991). More generally, the socio-economic literature discusses the difficulty in achieving a clear understanding of vulnerability, because it is often identified with only one of its causes (Delor and Hubert,

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[5] These types of economic valuation on environmental goods have been numerous during the last 20 years in Europe. The Data bases EVRI (Environmental Valuation Reference Inventory), ENVALUE and the Swedish valuation data base can be used to view a number of these studies.

[6] Definitions are also presented in this report for "Exposure": "The nature and degree to which a system is exposed to significant climatic variations" and "Sensitivity": "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli".

2000). In natural hazards science, three co-ordinates of vulnerability are underlined: the risk of being exposed to crisis situations (exposure), the risk of not having the necessary resources to cope with these situations (capacity), and the risk of being subjected to serious consequences as a result of the crises (potentiality). Finally, in the analysis of social cohesion, the complexity of socio-economic vulnerability is underlined (Sen, 1981; Moser, 1998), defining informal settlements according to 4 elements: degree of marginalisation, absence of opportunities for asset retention and growth, local perception of poverty, compromised use of space related to the access by emergency and service vehicles.

4 Challenges of applying threshold concepts at a regional level

The sections above have underlined the dimensions of uncertainty, relevance and robustness of an assessment. When it comes to the practical issue of applying these principles to a regional assessment, some further issues arise. There are likely to be differences in the values ascribed to limits, both within regions but particularly between regions. These arise for example from differential local values attached to economic growth *versus* environmental protection.

With interpretation of any type of limit, there are likely to be strong differences in the values ascribed to limits, both within regions but particularly between regions. To present some broad generalisations as examples, a wealthy, heavily urbanised or industrialised region is likely to place a high unit value on an environmental resource (e.g. nature reserve, bird species) than a predominantly rural region where that resource is plentiful and where there are other social priorities such as a high level of unemployment; but contradictory cases can be found for example in urbanised areas with severe problems of unemployment and priorities given to economic activities. These differences are not always clear-cut. For example, both an urbanised and a rural region may both strongly value areas of woodland but for different reasons. The former may see it as having amenity value in tourism and recreation, the latter may value it as a livelihood for local companies extracting timber. Thus, these differences in the value attached to limits may strongly influence the marginal costs and gains associated with a change in indicator value, relative to a limit.

4.1 Sensitivity of an indicator to reflect processes of change

If many different interpretations of the term ‘sensitivity’ are developed, the sensitivity of an indicator challenges its capacity to reflect processes of changes or relationship to factors outside the basic system which it describes.

In the environment, the sensitivity of an indicator/relationship may operate at different levels, and be governed by factors such as internal characteristics which differ on a regional basis. For example, management regimes in European grasslands can alter their sensitivity to eutrophication (in terms of species change) (Achermann and Bobbink, 2003) due to local variations in how grazing or hay cutting are carried out. An indicator may also be sensitive to external forces. For example, are relationships governing the level of methane emission from land-use types equally valid under different climate change scenarios? Moreover, the form or the realised extent of a relationship may differ regionally across Europe. For example, a farmland birds indicator is composed of abundance of a number of different species whose ranges differ across Europe. Therefore calculation of such an indicator will draw on different species and populations in each region for which it is calculated, with the potential for differing sensitivity to land use change.

These issues of data relevance are also present in socio-economic arenas (particularly where national average data is disaggregated and used to identify regional limits for indicators) and issues of indicator sensitivity (in terms of representativeness of the change and side-effects of this change). A number of factors influence the assessment robustness. One of them is the indicator sensitivity in regional assessment and the selection of indicators in terms of indicator adequateness – according to the processes targeted and the spatial scale considered - and data availability. Description of complex processes often demands composite indicators subject to some uncertainty (weighting, availability of data etc.). The GDP indicator gives a good example of this uncertainty. GDP is often one of the main parameters (with employment rate, rate of inflation, …) selected from the 70s to measure growth as an indicator of economic success (Gadrey and Jany-Catrice, 2005), but it is subject to increasing criticism, coming sometimes from economists but more often from other disciplines: sociologists (economic growth is not necessarily a measure of social well-being) or natural scientists (economic growth is often accompanied by environmental destruction). The GDP indicator refers mainly to growth and does not consider all dimensions of development (sustainable or not) especially an indicator of human progress or welfare[7], that will limit the scope of the assessment at regional level. Moreover, some European objectives are political targets leading to questions on the sensitivity of available indicators at pan European level (at Nuts X scale[8]), and potential hidden side-effects. Main objectives of a competitive, equal, sustainable and cooperative European union are underlined in European documents. These concepts are quite complex and there is little chance of finding indicators that can cover all aspects, and very few relevant indicators have yet been developed.

The sensitivity of an indicator may vary at different spatial scales, or may differ geographically depending on local conditions. For example, patterns of connectivity within a landscape unit are relevant at a range of scales from tens of metres to hundreds of kilometres depending on the mobility and territory size of species, but also in the long term for providing avenues for range extension or adaptation under conditions of climate change. Sensitivity of a socio-economic indicator has also to be questioned according to the spatial scale. If indicators, on the basis of socio-economic data, are available only at the national level, their effectiveness or even meaningfulness at a lower level can be highly questionable. Sensitivity of an indicator may vary at different spatial scales.

4.2 Ability of a system to recover from stress and consequence of change

An important aspect in understanding sustainability is the way an environmental or socio-economic system recovers from stress, and what are the consequences when a limit is passed.

It is recognised that the factors which tip an environmental system over a limit may be relatively minor or chance events, and that the key issue is the resilience of the system to deal with these, i.e. resilience is the ability to absorb perturbations and still persist (Holling, 1973, 1986). One example based on habitat fragmentation thresholds for woodland bird diversity illustrates this property. In a highly connected habitat, stochastic events

[7] A. Sen (1996) has also challenged GDP as a meaningful indicator and has inspired in the United Nations Development Programme the Human development index to monitor the state of human development in the world. This index is calculated by averaging the indicators related to the 3 following aspects: Life expectancy at birth; education (measured by adult literacy and educational enrolment rates) and GDP per capita.

[8] NUTS X regions are the spatial level at which the majority of the indicator calculations are processed in the SENSOR project. They are an amalgamation of the NUTS 2 and NUTS 3 administrative units of the EU.

such as storms or fires which cause a small or temporary decrease in available habitat are not likely to affect the bird population size. However, as the habitat thresholds are approached and resilience (habitat connectivity in this case) decreases, stochastic events which are relatively small in magnitude have the potential to over-reach the limit, with severe consequences for the bird population.

In the same direction, extensive socio-economic work has been done on causes and impacts of livelihood shocks (Sen, 1981; Davies, 1993; Devereux, 1993; Putman, 1993). This has inspired a large number of urban studies of household responses to economic crisis, studying the ability to recover from a stress, and of structural poverty reduction strategies focussing on assets of population (Moser, 1998). Especially, urban studies have questioned the ability of the population to cope with the consequences of the insecurity (Downing, 1991), from the sensitivity of a population to its responsiveness. C.O.N. Moser (1998), categorised the assets of poor urban individuals including: tangible assets (labour, human), productive assets (housing) and intangible assets (household's composition and structure, cohesion of family members, mechanism for pooling income and sharing consumption, social capital –reciprocity within communities and between households). In addition, recent conceptual debates and policy recommendations – deriving from rural famine, food security research, have introduced also in the social and development debate concepts of vulnerability or sensitivity.

Another property of some indicators that has to be taken into account is "path dependency", where the sequence of events over time determines the end point or character of the system, In socio-economics, "path dependency" is defined as where the development process is embedded depending on its past history, on the entire sequence of decisions made by agents and resulting outcomes, and not just on contemporary conditions. In these local dynamics each step of a new equilibrium depends on the path already taken from the initial situation. Similar considerations apply in the field of technological research, showing also how technological regimes are channelled – (path dependent) in a 'technological paradigm' (Dosi, 1988).

The concept applies also for environmental systems where the sequence of events over time determines the end point or character of the system, rather than a combination of factors resulting in a guaranteed endpoint once a set of ecological requirements have been met. For example, vegetation assemblages could be seen as path dependent, where the composition of a plant community depends on migration rates of different species as the climate changes, and on evolutionary change and stochastic factors governing success or otherwise of particular species. A related concept is hysteresis, which shows that reversing a set of conditions does not always reverse the consequences at the same time or in the same way; in other words the relationship may change. This is illustrated in Figure 1b above where the shift in an environmental system from state A to state B occurs at one level of environmental pressure but when conditions are reversed, the switch back to state A occurs at a different point. For example, with respect to soil acidification, once soil pH has dropped below a certain level, even if anthropogenic inputs of acidifying compounds are drastically reduced, the time taken for natural replacement of base cations in the soil profile depends on the rates of mineralisation of parent rock and can take decades, or even centuries (Reynolds, 1997). This has strong implications for the reversibility of limit exceedance.

Therefore, a key issue in the assessment is how important limit exceedance is, and whether the former condition can be regained (reversibility). In some cases, once a limit is exceeded, this is an absolute position, which can not realistically be returned from. For example, following expansion of urban residential area into formerly agricultural land use, it is highly unlikely, or extremely costly, to reverse that change. Recovery from some situations is technically possible but due to cost, timescale, political or social considerations it becomes effectively impossible. Other changes may allow full or partial recovery, for example land abandonment due to rural depopulation, or reducing pollutant inputs to the environment and in these cases reversibility should be aimed for. In essence, these factors of path dependence and reversibility help inform the consequences of limit exceedance, in that they have cost and timescale implications which must be taken into consideration when defining values for limits.

5 Conclusion: Identifying regional values for limits and sustainability boundaries

Does it matter if the system switches? Is the change, to all practical purposes, absolute, or to what degree can it be reversed? What are the cost and resource implications? The way to answer these sorts of questions may be quite different between environmental sciences and socio-economic sciences. However, both raise the question of how these can be adequately analysed, interpreted and managed.

When identifying values for limits, a number of issues need to be considered. They take into consideration the socio-economic and environmental consequences of the exceedance of limits to a large extent linked to the reversibility of a system (the likely cost of achieving reversibility) and to its dependence on past history (concept of “path dependency”), on the entire sequence of decisions made by agents and resulting outcomes, and not just on contemporary conditions. In a more obvious way, path dependency is apparent in regional development assessed within SENSOR. In these local dynamics each step of a new equilibrium frequently depends on the path already taken from the initial situation. Therefore, the purpose is not to define a limit before or above which the regional dynamics change, but to understand irreversible phenomena which define for each region possible future paths.

Together with a concept of risk, often illustrated within the growing field of vulnerability assessments, acknowledgement of all these concepts leads us to apply a *precautionary principle*, in other words to set conservative limits that define ‘unacceptable consequences’ some distance in advance of the point (or area) at which system break down or severe damage occurs. Crucially, this setting of limits demands consensus and involves both social acceptability and political input, together with scientific understanding of how the system operates (be it socio-economic or environmental). In environmental systems risk is indeed usually related to limits, beyond which we see unacceptable consequences and the desire is to remain as far from that limit as possible. In social and economic systems the social dimension of risk is emphasised. UNESCO underlines its double dimension: risk is a crossing product between hazard – probability of occurrence of an event with certain intensity (avalanches, river flood…) - and vulnerability – exposure to socio-economic issues linked to this hazard (goods, human beings, activities …).

Taking into account these issues is necessary to identify the boundaries of sustainability. These are often considered in vulnerability assessments either explicitly or implicitly. Together, they define the social, economic and environmental costs which determine the effective consequences of limit exceedance, and therefore the political weight to be attached to avoiding that exceedance.

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Sustainability Impact Assessments: limits, thresholds and the Sustainability Choice Space

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Abstract

Sustainability impact assessments (SIA) are inherently difficult because they often require policy advisors to compare things that are not easily compared. For example, they generally require an evaluation of policy proposals or options across the 'three pillars' of economy, society and environment. In this chapter we explore how decisions are made in relation to questions about the sustainability of policies, and show how the consideration of sustainability limits can help integrate thinking across the economic, social and environmental domains. It is argued that in relation to questions about the sustainability of actions or policies, outcomes merely need to be sufficient to maintain human well-being and that the search for optimal strategies is probably misleading. The concept of a sustainability choice space is developed as a way of helping policy advisors visualise and explore what 'room for manoeuvre' they might have in the design of a specific policy. The sustainability choice space can be used to describe the degree to which alternative policy outcomes are acceptable to stakeholders across a range of criteria. The chapter concludes with a discussion of the role that the concept of a sustainability choice space might have as part of the sustainability impact assessment toolkit being developed through SENSOR, and how it can be extended by the involvement of stakeholders in the definition of sustainability limits and the kinds of trade-offs that need to considered in a multifunctional landscape.

Keywords

Sustainability Impact Assessment, sustainability limits and thresholds, policy choices, multifunctional landscapes, Land Use Functions.

1 Introduction

Sustainability impact assessments (SIA) are inherently difficult because they often require policy advisors to compare things that are not easily compared. A core principle of sustainable development is that the 'three pillars'[1] of economy, society and environment must be respected, but how should changes in these different factors be characterised and ultimately weighed against each other?

Approaches to the problem of characterising the potential economic, social and environmental impacts of policy actions are now well established – at least conceptually if not practically. Indicators have emerged as a major tool for scientists and policy makers alike, and they are widely used to represent key elements of systems and to track trends. Increasingly models are now being employed to think about the changes that might be set in train by different policy options. The SENSOR Project[2] is firmly part of this tradition. Its goal is to develop a Sustainability Impact Assessment Tool (SIAT) that can somehow help policy advisors integrate the range of issues that need to be taken into account if the implications of policy decisions for sustainable development are to be fully evaluated.

In this chapter we examine some of the features of SIAT, and in particular reflect upon the problem of integrating information and framing decisions across the three pillars of sustainability. The discussion will focus on the concept of a 'sustainability choice space' which is proposed as a way in which policy advisors might visualise and explore what 'room for manoeuvre' they might have in the design of a specific policy. We will show how the idea of a sustainability choice space might be used to describe the

[1] We use the term "three pillars of Sustainability" although we agree with Kemp et al. (2005, p.3) that "the pillar-focused approaches have suffered from insufficient attention to overlaps and interdependencies and a tendency to facilitate continued separation of social, economic and ecological analyses." … and …that the overlapping circle idea comes closer to the integration of the three parts of Sustainability.

[2] "Sustainability Impact Assessment: Tools for Environmental Social and Economic Effects of Multifunctional Land Use in European Regions", Integrated Project within the EU 6th framework programme (www.sensor-ip.eu)

degree to which alternative policy outcomes are acceptable to stakeholders across a range of criteria. We also describe how such a choice space must be constructed using information derived from stakeholders to identify the dimensions of sustainability, which are important in the context of a specific policy and the limits and thresholds associated with them.

2 Sustainable Development: Ultimate vs Adequate Solutions

In order to show why the idea of a sustainability choice space is so important for those involved with SENSOR, it is worth reflecting further on the reasons why SIA (or sustainability appraisals in general) are so difficult. Not only do we face difficulties in terms of trying to resolve issues between things that are not easily compared – economy, society and environment – we also have to wrestle with the fact that 'right answers' are difficult to recognise.

Many commentators have argued that 'traditional science' is singularly ill-equipped to cope with the problems that sustainable development throws up (Holling, 1998; Kates et al., 2000; Gallopín et al., 2001). Holling (1998), for example, has attempted to contrast the features of traditional science and its analytical traditions with a more 'integrative' approach that seems more appropriate in the context of sustainability (Table 1). With its narrowly targeted, reductionist methods, that strive for ultimate but parsimonious solutions, the danger is, according to Holling (1998) that we achieve the 'right answer for the wrong question'. By contrast, it is claimed that contemporary problems, particularly those involving notions of sustainability, call for broader, more exploratory problem solving strategies that results in solutions that are essentially 'consensual'. We are witnessing, according to Gallopín et al. (2001) a 'diversification in types of knowledge production that are regarded as legitimate' and a 'democratisation of knowledge' so that the insights of lay and indigenous people are no longer regarded as in some sense inferior to that of experts.

Table 1. Two traditions of science (after: Gallopín et al. 2001, and Holling, 1998)

Attribute	**Analytical**	**Integrative**
Philosophy	Narrow and targeted Disproof by experiment Parsimony the rule	Broad and exploratory Multiple lines of converging evidence Requisite simplicity the goal
Perceived organisation	Biotic interactions Fixed environment Single scale	Biophysical interactions Self organisation Multiple scales with cross scale interactions
Causation Hypotheses	Single and separable Hypotheses and null rejection of hypotheses	Multiple and only partially separable Multiple, competing hypotheses Separation among competing hypotheses
Uncertainty	Eliminate uncertainty Standard statistics Experimental Concern with Type I error (in hypothesis testing, rejecting the proposition when it is true	Incorporate uncertainty Non-standard statistics Concern with Type II error (failing to reject the proposition when it is false)
Evaluation goal	Peer assessment to reach ultimate unanimous agreement	Peer assessment, judgement to reach a partial consensus
The danger	Exactly right answer for the wrong question	Exactly right question but useless answer

While arguing for the integrative approach, Holling (1998) acknowledges that it is not without its dangers. These include the possibility that wide consultation and discussion may result in formulating the right question, but that ultimately the methods may not guarantee an appropriate or satisfactory answer. However, while it is certainly the case that science increasingly has to take account of the interaction between experts, decision makers and the public (Figure 1) it does not follow that traditional science and the methods of conjecture and refutation have no place in current debates. What these critiques of traditional science lack is any recognition that there is a fundamental difference between the sorts of problems we face in the scientific and policy realms.

The differences between the problems encountered in the scientific and policy realms can best be seen in terms of how solutions are regarded. For the scientist, theories (= solutions) stand or fall according to whether they are supported or refuted by evidence about how the world works. The guiding principle is that there is only one true explanation and that through trial and error, or conjecture and refutation, that answer might ultimately be discovered. Solutions to questions involving sustainable development are not usually like this, for here - while solutions must not ignore biophysical, economic or social constraints - many different organisational strategies or policies can deliver outcomes, which have the capacity to ensure social justice, well-being and inter-generational equity. Solutions to the problems of sustainability merely have to be sufficient or adequate, not ultimate, and so we may be presented with a choice of many ways forward. We do not, in other words, need to find 'a best' or 'optimal' solution. Indeed there may not be one. 'Success' ultimately depends on finding an adequate solution.

The difference between 'ultimate' and 'adequate' solutions is well illustrated by different ways of thinking about land use patterns and sustainable development – the type of problem that is a central concern to projects such as SENSOR.

Forman (1995), for example, has hypothesised that for any landscape, or major portion of the landscape, there exists an optimal spatial arrangement of ecosystems and land uses to maximise ecological integrity. He argues that the same is true for achieving basic human needs and for creating a sustainable environment. As he looks to the future, he argues that 'the major but tractable challenge' is to discover what those arrangements are.

The view that the search for optimal spatial arrangements are the major challenge confronting land use science can be contrasted with an alternative vision, which envisages that if our goals include ecological integrity or continued human well-being, then many different spatial arrangements of land cover and use are likely to be able to achieve such ends (cf. Potschin and Haines-Young, 2006). Thus while we might acknowledge that a certain level of woodland cover is necessary to maintain biodiversity, and that a certain degree of fragmentation should not be exceeded, those criteria can be met by many different arrangements of woodland parcels across a landscape.

It is now widely acknowledged that whatever sustainable development involves, it certainly embodies the idea that the output of ecosystem goods and services from landscapes or ecosystems should be maintained (MA, 2005). 'Sustainability' is, we suggest, assessed more in terms of the ability to maintain functional outputs than by structural properties *per se*. Thus we would argue, in contradistinction to Forman (1995), that the major challenge confronting land use science is to understand what possible spatial arrangements are sufficient to maintain the outputs of goods and services that people value, and what types of arrangement are unlikely to achieve such ends, and thus to identify the ***range of planning choices*** that are available to us (cf. Haines-Young, 2000; Potschin and Haines-Young, 2006).

An understanding of the difference between ‘ultimate’ or ‘optimal’ and ‘adequate’ solutions in the context of sustainability is of fundamental importance for anyone attempting to design impact assessment tools. In searching for appropriate problem solving strategies we need to look no further than the example of the process of evolution by natural selection, which also operates on the basis that at any one time, new forms do not need to be optimal, but simply sufficient to improve survival over other varieties (cf. Sartorius, 2006). The difference between the two processes is merely that under sustainability planning, the strategy that ‘survives’ is determined more by social negotiation than competition. Sustainability impact assessment is essentially normative rather than prescriptive, and is based on an understanding of the ways in which economic, social and environmental considerations constrain our planning choices.

The search for adequate or sufficient solutions, rather than ultimate answers is, in fact, implicit in the ‘adaptive’ and ‘flexible’ approaches espoused by the champions of so-called ‘sustainability science’ (e.g. Kates et al., 2000, 2001). Indeed, as Kemp et al. (2005) have pointed out sustainability is best approached as an open-ended process, and that the notion of sustainable ‘landing places’ that is sometimes used by the European Commission is probably misleading. As Kemp et al. (2005) note, such ideas suggest that the problem of sustainable development can be ‘solved’ whereas in reality only specific issues can be resolved and managed.

3 Constraining Choices: Limits and Thresholds

Questions about environmental limits, and their implications for policies related to sustainable development have recently emerged as an important focus of debate in the scientific and policy literature (e.g., Sagoff, 1995; Lomborg, 1998; Davidson (2000)[3]. These discussions are, in fact, part of a much longer and wide-ranging discussion about the extent to which human development can be maintained in the light of supposed environmental constraints. Going back to the late eighteenth century, for example, Malthus (1798) considered the limiting relationships between population growth and food supply. In the twentieth century discussion of resource constraints was stimulated by the publication of *Limits to Growth* (Meadows et al., 1972) which argued that in a finite world, economic expansion could not be sustained indefinitely. In the contemporary literature, the recent notions of limits have been framed around the ideas of ‘ecological

[3] See also Bertrand et al. (2008)

footprints' and 'sustainable patterns of consumption and production', both of which imply that there are limits beyond which certain types of growth and development are not sustainable. Such ideas are also now actively being discussed in the political arena, for example, in relation to ideas of 'one planet living'[4].

If, in the context of making sustainability assessments, economic, social and environmental limits or thresholds constrain or frame the choices that we can make, how do we go about defining them? Unfortunately the task is not an easy one, because different discipline areas have approached the problem in different ways. We thus begin with some clarification of terminology (see Bertrand et al., 2008).

A review of the ecological literature suggests that although the terms 'limit' and 'threshold' tend to be used interchangeably, it is useful to distinguish between them because they highlight important features about system behaviour that ought to be considered when developing policy or management strategies. Ecosystems are, for example, important to people because of the benefits they actually or potentially deliver and the contribution they make to human well being (MA, 2005). However, external pressures may progressively undermine the capacity of these systems to continue to deliver those benefits at the level required. As a result, society may judge that a 'critical point' has been reached, beyond which further change is unacceptable. This critical point denotes what most commentators call a limit (Figure 1a).

The term threshold, by contrast, is probably best used to describe situations where a sudden regime shift occurs, because the system can exist in alternative stable states. In this case, the 'threshold' is that point at which systems become vulnerable to such behaviour.

The study of thresholds has recently become the focus of attention in the environmental literature, largely because of the dramatic nature of the change that can be triggered once a threshold has been crossed (Scheffer et al., 2001; Scheffer et al., 2003; Scheffer and Carpenter, 2003). Such behaviour is well known in aquatic systems impacted by eutrophication, for example, where increased nutrient loading may cause the sudden loss of ecological integrity, which cannot simply be restored by reducing pollution loads due to hysteresis effects (Figure 1a). However, while there have recently been some attempts to document such behaviour (Walker and Meyers, 2004), and explore the extent to which it may be exhibited by 'coupled ecological-social systems', it seems that such dynamics are by no

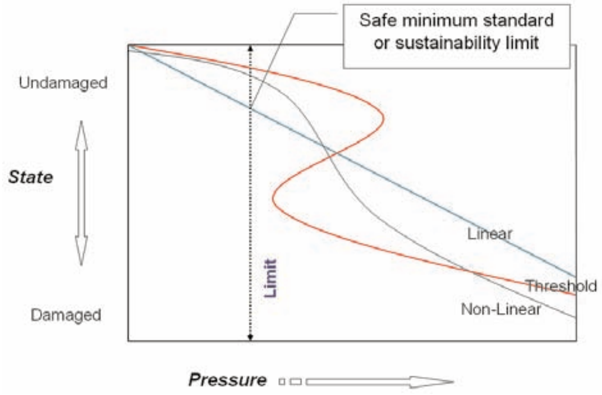
[4] international http://www.oneplanetliving.org/ , also recently promoted by the UK Government http://www.defra.gov.uk/news/latest/2006/defra-1013.htm, http://www.cpi.cam.ac.uk /bep/downloads/one%20planet%20living.pdf

means universal and that the existence of threshold effects are difficult to predict before they are observed.

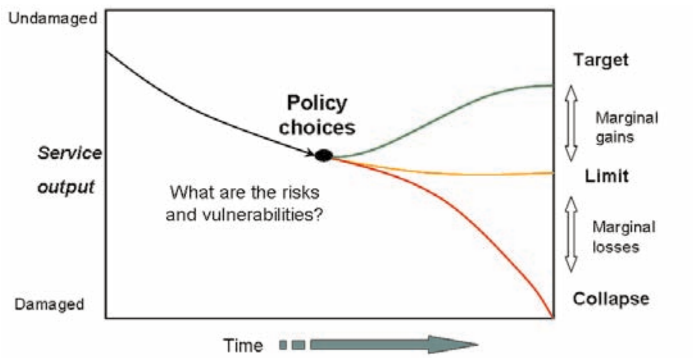
Without denying the possibility that systems may exhibit threshold responses, we would argue that when making sustainability assessments, the more general idea of a limit is probably more useful – and certainly less ambiguous. Limits can be defined for all types of system, whether they exhibit a progressive linear decline in the face of external pressures, whether change is progressive but non-linear, or whether there may ultimately be some collapse if the system experiences a ‘regime shift’ or threshold response (Figure 1a). The idea of a limit can be used to deal with the dangers of sudden collapse (due to threshold-type responses), but at the same time can focus attention on possibly the more widespread situation where there is a chronic or gradual loss of the functionality as a result of increasing economic, social or environmental pressures on resource systems. A limit can be defined whether the system shows a threshold response or not.

In fact, as Figure 1b suggests, different types of limit can be envisaged, depending on how society wants to cope with the risks associated with loss of function or benefit. Thus while absolute limits might be recognised, management might aim to keep the system above some ‘safe minimum standard’, or ‘precautionary limit’ that ensures that the danger of collapse or significant damage is not extreme, given the presence of uncertainty and environmental variability[5]. Although the idea of a limit is a simple one, there is a hidden complexity in the way they are defined, which must be discussed if we are to make successful sustainability assessments. This complexity arises from the fact that the identification of a limit ultimately hinges on the judgment made by individuals or groups ‘that a critical point has been reached’. How, we might ask, is that judgment made and justified? We would argue that is mainly in terms of the perceived or predicted consequences or implications of exceeding a given limit that those judgments are made.

[5] In context of sustainable fisheries, the safe minimum standard is often referred to as a ‘precautionary reference point’.



a) Systems can show a range of responses to some external driver. The responses may be linear or non-linear, or show 'threshold' behaviour, involving a regime shift. The concept of a limit can be used to specify the extent of acceptable change in terms of the levels of benefit the system can generate or the risks and uncertainties involved in approaching some threshold.



b) Faced with increasing levels of damage, there may come a point at which society looks at the policy options, ranging from maintaining the status quo (i.e. deciding that some limit of acceptable change has been reached), restoration or enhancement of function, or of allowing collapse. The choice between options depends on weighing the marginal gains and losses in relation to some limit.

Fig. 1. Relationship between thresholds and limits and different types of system response to environmental pressures (adapted from Haines-Young et al., 2006

Consider, for example, the problem of climate change, and the recent argument put forward that unless the level of emissions of green house gasses are curtailed, then *unacceptable* levels of damage to the economy may result. The limit being discussed is a warming of no more than 2°C. The interesting thing to note about this debate is that while physical scientists can point to a range of consequences that different levels of warming might have[6], ultimately the particular limits that will be agreed will emerge as a result of a socially negotiated process. This process will be conditioned, to a large measure, by different views people take about levels of risk, possible costs and ideas about the speed at which societies and economies can adjust to long term climate change.

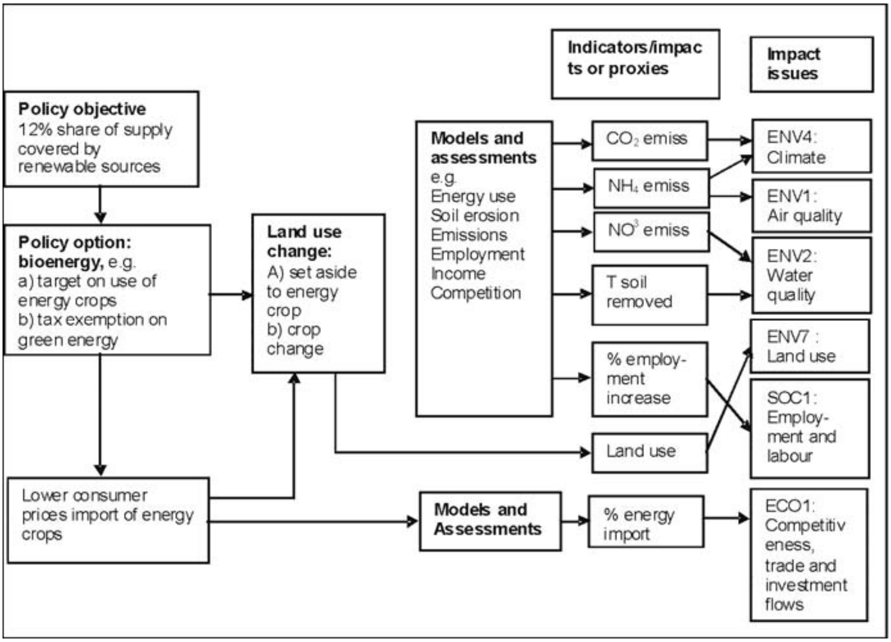


Fig. 2. Simple cause-effect model describing the potential impacts of biofuel policy options on a range of indicators and impact issues (after Frederiksen and Kristensen, 2008).

Alternatively, consider the scenario that significant land areas in Europe might be turned over to the production of biofuels. The consequences of different policy options can potentially be modelled[7], and outcomes char-

[6] Including the existence of possible threshold responses, such as the disruption of the north Atlantic conveyor, or the melting of the Greenland Ice Sheet.

[7] See also Kuhlman et al. (2008), and SENSOR indicator framework, and methods for aggregation/dis-aggregation – a guideline,

acterised and compared in terms of the implications that different levels of biofuel production might have for a range of economic, social and environmental indicators (Figure 2). Faced with different scenarios - what factors constrain our possible policy choices? Once again it is the judgements we make in partnership with experts and stakeholder groups, about whether, for particular indicators, critical limits are breached and how we might prioritise issues if trade-offs between costs and benefits have to be considered.

Sustainability impact assessments are difficult not only because they force us to compare things that are not easily compared, but also because they are multi-dimensional. In making assessments we have to take account of many different types of limit, most of which cannot be fixed *a priori*. The discussion, identification and setting of limits is, it seems, part of the 'democratisation of the knowledge' that many now see as an essential element of contemporary scientific and policy debates.

4 Multi-dimensional decision making: The Sustainability Choice Space

The identification of limits across the three pillars of sustainability is important because these limits constrain our policy choices. In the context of projects like SENSOR, the goal of comparing policy options through sustainability assessment is not to discover some optimal solution, but to find strategies that are sufficient or adequate, in terms of maintaining over time the benefits that land use systems can provide. We can visualise the process in terms of the model described in Figure 3, which illustrates the idea of a sustainability choice space in relation to different trajectories of land use change.

The goal of SENSOR is to provide a set of tools that can be used to evaluate the impacts of policy decisions as they are expressed through changes in land use.

The approach adopted involves identifying a set of economic, social and environmental indicators linked to land use, which allow us to trace the consequences of different policy options. The fundamental assumption is that land use change is the key driver.

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http://lis4.zalf.de/home_sensor/upload/modul1/Reporting%20Deliverables/Deliverables%20Module%205/SENSOR_del_5.2.2_with_annexcomplete.pdf

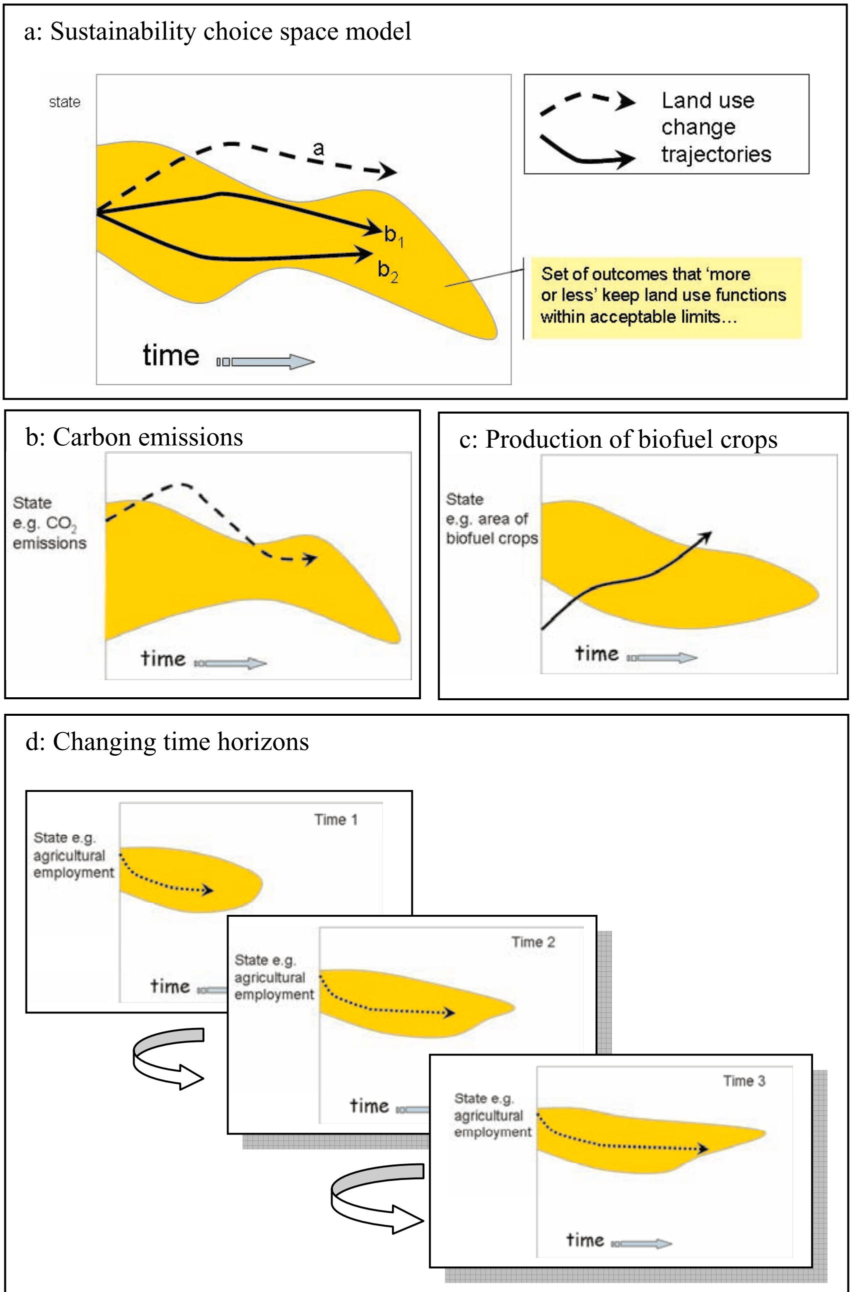

Fig. 3. The Concept of the Sustainability Choice Space

Thus in the simplest case we could characterise the dynamics of the system that we are interested in by a single indicator[8] that reflects these land use changes, such as ‘CO_2 emissions or ‘the area of biofuel crops’.

For those concerned with assessing the implications of some policy measure the key question is whether the land use trajectory is likely to take us out of the region beyond which some critical limit is reached for the indicator that we are interested in. We suggest that this critical region can profitably been seen as the ***sustainability choice space***, in that it expresses the room that we have for manoeuvre in designing our different policy options. If current land use trajectories are likely to take us outside the critical region then we can ask questions about what types or level of policy intervention might bring us back within limits (Figure 3, trajectory a). If we perceive that in the future our views of limits might need to be changed, then we might ask what options there are for ensuring that future trajectories continue to sustain the level of benefits we currently enjoy (Figure 3, trajectory b_1 and b_2). In Figure 3, since trajectories b_1 and b_2 are likely to keep us within acceptable limits then both can be regarded as ‘adequate’ or ‘sufficient’ in sustainability terms. The decision between them is essentially a matter of social or political choice, and it is within this space that trade-offs between various types of benefits can be discussed.

The model shown in Figure 3a is simplistic, however, and several important features should be noted to see what insights it has for understanding real world situations.

First, the shape of the choice space can change over time. A sustainable trajectory of land use is one which maintains the output of the goods and services that are important to well-being. That is, it remains within the limits that society has identified, or agreed on, as significant. This is the issue that is being captured by the indicator. However, clearly the view that society has about limits can change, and so a trajectory that was once thought of as unproblematic can become so. The problem of CO_2 emission is a case in point (Figure 3b). Improved scientific knowledge now suggests that emission loads need to be significantly reduced - thus over time we can see that the choice space has been reduced in terms of the upper limits of emissions that are considered allowable. At the same time, there is probably a lower level of emission, below which the costs or risks of further carbon emission controls would probably outweigh the benefits. Again this may change with, say, changes in technology such as carbon storage. The

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[8] In the case of SENSOR, a set of high level, aggregated indicators known as ‘land use functions’ (see Perez Soba et al., 2008), will be used to summarise the affects of different policy. The argument presented here applies whether we use a single indicator or an aggregated land use function.

point is, however, that there is scope for policy choices between these limits, and any informative sustainability assessment has to be framed around notions of where these limits lie.

The same point can be illustrated by reference to the biofuel case shown in Figure 3c. Here we start from the position that biofuel output is probably below what Society requires, given the need to reduce the consumption of fossil fuels. Thus while policy changes may stimulate the expansion of such crops, there is likely to be an upper limit to such an expansion in particular areas, beyond which the wider impacts of the new land use patterns become unacceptable. For example, given the need to sustain and enhance farmland bird populations, the replacement of traditional forms of arable farming with short rotation coppice, may conflict with this aim. Moreover, the expansion of large areas of woody crops may also impact on the visual and aesthetic qualities of landscapes. Once again views about what constitutes the upper and lower limits may change over time, and crucially may be contingent on the character of the particular landscape or set of landscape types that we are dealing with.

The second point to make about Figure 3 is that while the shape of the sustainability choice space may change over time, it is generally impossible to identify some 'ideal' or 'final' state. Thus in the figure, the choice space is 'closed off' – since the future is hidden. As time passes, however, the corridor defined by that we perceive limits 'opens up', as the future 'reveals' itself. This is illustrated by the example in Figure 3d, which has been constructed around the issue of 'agricultural abandonment'.

In many areas of Europe, agriculture is economically marginal, and land abandonment has become an important driver of land use change in these areas (Swaffield and Primdahl, 2006). In Figure 3d, the indicator used as a proxy for this process is the level of agricultural employment, which is shown to be declining slowly over time. At each time step, however, our view of the future may be different as our perspectives and understanding of economic, social and biophysical limits change. Thus a trajectory that was thought initially to be 'within tolerance limits' may eventually be judged to be 'unsustainable' if, for example, our notion of what constituted a minimum level of employment changed. This might arise, for example, as our views about the levels of rural population needed to maintain rural services changed, or as the result of increased concern about the risk of fires in landscapes that are undergoing succession back to woodland as a result of land abandonment.

The third point to note about the idea of a sustainability choice space is that although we may plot the state of the system in terms of a single indicator that reflects some aspect of the economic, social or environmental characteristics of the land use system, the notion of a limit helps us integrate thinking across the three pillars of sustainability in ways not easily achieved by current indicator approaches. The level of agricultural employment in rural areas (Figure 3d), for example, could be viewed as an economic indicator, but it clearly has environmental consequences, since it can affect a range of physical characteristics of an area. Withdrawal of farming may not only change risks associated with fires, for example, but also the visual properties of a landscape, which once gave it its 'sense of place'[9]. Similarly the limits associated with an environmental indicator such as CO_2 emissions are ultimately also determined by social and economic considerations that include the costs and risks associated with the sorts of investment that might need to be made to trigger particular land use changes (e.g. reduced input agriculture) on a sufficient scale to make a difference.

The final point to make about the model shown in Figure 3 is that in reality the choice space is multi-dimensional. Sustainability assessments need to take account of many factors, and these can be expressed in different ways. As we have seen, some aspects of 'multi-dimensionality' can be accommodated in the way limits are expressed. We have argued that judgements about what constitutes a limit generally bring together a range of economic, social and environmental issues. Thus the model shown in Figure 3 is in some sense already multi-dimensional - even though it focuses on a single indicator. The representation could be further enriched and extended by using some aggregated, or 'high level' indicator, such as the land use functions proposed by the SENSOR team. However, clearly the representation of the choice space could also be made even more comprehensive by including other indicators and the limits that apply to them as extra dimensions to the graph. Such multi-dimensional thinking is, of course difficult to represent, and we will consider the problems this poses for the design of policy assessment tools in the final section of this paper. At this stage it is important to note that in principle, thinking about limits in relation to some set of indicators can help policy customers understand how policy choices might be constrained, and ultimately what options are available, given the goals of sustainable development.

[9] What qualities for example make 'The English Lake District' or the 'Black Forest' so distinctive? What is the essence of 'Tuscanyshire' that makes it such a focus for recreation and holiday home development amongst the British?

5 Sustainability Choice Space: Case Studies

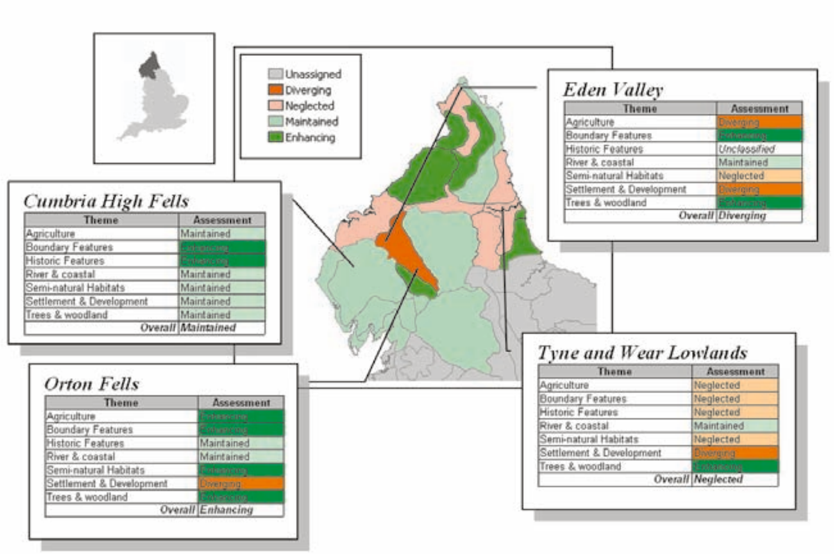
The idea of a sustainability choice space in relation to issues of land use change is relatively new, and has mainly been discussed in conceptual rather than practical terms (Potschin and Haines-Young, 2006). As an emerging idea, however, it has resonance with thinking in other discipline areas. In addition to the general debate about the need to live within limits noted in our introduction, the idea is analogous with concepts discussed in the literature on sustainable consumption and production, where concepts such as 'sustainability spaces' (Binder and Wiek, 2001), 'solution spaces for decision-making (Wiek and Binder, 2005), and 'sustainability corridors' (Bringezu, 2006), have been proposed as a way of looking at indicators and the messages they convey. In the more ecologically orientated literature, Kaine and Tozer (2005) have in the context of agricultural systems, attempted to conceptualise sustainability as a set of boundary conditions. These workers develop a 'pasture envelope' concept in the form of phase diagram in which the trajectories over time of key biophysical variables such as pasture biomass and composition are graphed against critical thresholds established on the basis of pasture growth rates and livestock growth requirements.

The idea of a 'sustainable trajectory' through some kind of choice space is also echoed by recent discussions in the sustainable development literature on 'transition management' (Wiek et al., 2006; Tukker and Binder, 2007; Kemp et al., 2005). Transition management is a general term that deals with issues of governance related to sustainability, and is proposed in the Netherlands as a way of replacing outcome-based planning with more adaptive and reflexive approaches. The concept represents sustainability as a process or journey, rather than some end point, and stresses the fact that strategies should 'not aim to realise a particular path at all costs' but rather to explore all promising paths 'in an adaptive manner' (Kemp et al. 2005, p. 25).

In terms of providing a practical example of the application of the idea of a choice space, the concept can be partly illustrated by reference to a recent study undertaken in the UK, which has dealt with the problem of land cover change and its impact on landscape character (Haines-Young et al., 2008) (Figure 4). This study, known as *Countryside Quality Counts* (CQC)[10], considered landscape character in terms of seven key themes: woodland, boundary features, agriculture, settlement, semi-natural cover, historic features and river and coastal elements. For each of the major landscapes in England, data showing how these elements were changing

[10] Project homepage: http://www.cqc.org.uk/

were compared to the visions which stakeholders had for these areas. The visions were used to identify the desired direction and scale of change for each of these elements, and a judgment was made about whether overall landscape character (i.e. local distinctiveness) was being maintained.



Notes:
This is an extract of the CQC Second Phase Assessment which has considered the impact of change on countryside character in England between 1998 and 2003. The spatial units are Joint Character Areas (JCAs) of England, which describe the major cultural landscapes at the mesoscale. The nature of change across the seven themes that define countryside character have been assessed in terms of whether those changes are maintaining or enhancing local distinctiveness, whether the changes are transforming the area, so that character is diverging from traditional patterns, or whether, if past change had eroded character, the area is stable but neglected. Although all of the JCAs in England have been assessed, only four contrasting areas from the north of England are shown here. The overall assessment for each JCA takes account of stakeholder views about countryside change and its implications for countryside character, and which of the seven themes are most important in terms of what defines the area's 'sense of place'.

Fig. 4. Representing change in countryside character in terms of a 'choice space'

Figure 4 shows the major landscapes of England that can be identified at the national scale. For each spatial unit an analysis has been made of how, for example, recent changes in woodland cover and woodland management, and patterns of agricultural land use relate to targets that local stakeholders have identified as appropriate in terms of sustaining the landscape character of each area. An expert-led judgment has been made about the scale and direction of change in relation to the information supplied by stakeholders. Thus each landscape area has been assigned to one of a number of categories depending on how they are changing across all seven landscape themes considered. If the landscape character of an area is largely intact, then depending on the magnitude of change, each area is classified as being maintained or restored (enhanced). Alternatively, if in the past the character of the area had been eroded, and there is little recent evidence of change that would tend to restore it, then the area is described as neglected. Finally, if the area is changing in ways that are inconsistent with its traditional character, then the area is classified as diverging.

The analysis made in *Countryside Quality Counts* differs from that which will be attempted in SENSOR, in that it has not been designed to model the possible consequences of different policy options. Rather the purpose of *CQC* was to trace the outcomes of existing policy measures that have impacted on the rural landscapes of England. Nevertheless, the study does illustrate something of the sustainability choice space concept, in that it shows how, through consultation with stakeholders, the issues that matter in terms of sustaining the quality of different landscapes can be identified, and sustainability limits defined. These limits have been used to assess patterns of change for each of the seven landscape themes, represented by a set of indicators, such as ‘woodland cover’, or ‘area under agri-environment agreements’, and to determine whether certain critical limits have been crossed. These limits have then been used to make a judgment about whether changes in a set of indicators describing the characteristics of specific geographical areas lie outside this ‘socially negotiated’ suite of boundary conditions.In this way the project has been able to answer the type of question that eventually SENSOR will have to consider, namely ‘where is land cover change occurring?’ and ‘do those changes matter?’

6 SIAT and the Sustainability Choice Space

In the final part of this chapter we turn from the general issues surrounding the sustainability choice space concept to look at the specific problems associated with implementing it as part of SENSOR’s sustainability impact assessment toolkit.

In terms of providing information that can be used by policy customers, the practical problem faced in designing SIAT is how to move from a set of spatially disaggregated indicators describing the modelled consequences of land use change, to some integrated view that can help users to make a sustainability assessment. In order to ensure the greatest flexibility of the interface, it is likely that a range of information handling tools will be provided.

The early SIAT prototypes[11] have shown how users can be given access to real and modelled trajectories for a range of individual social, economic and environmental indicators at 'NUTSx' level (Petit et al., 2008). In addition to providing metadata for each indicator, the system will be designed to inform users about any limits that are associated with particular indicators, and thus begin to provide them with the types of information that can help them explore the implications of a particular policy case or option. As a general principle, users should clearly have access to the most disaggregated information that is available. However, for such a potentially large and diverse body of information to be useful in decision-making, tools to help users summarise the information would also be valuable.

The proposal that individual indicators can be grouped into a set of nine broad 'land use functions' (see Perez-Soba et al., 2008) is a first step in this data aggregation process. These functions can be used to see how in a more integrated sense, the changes in individual indicators might impact on the wider aspects of human well-being and the environment. In order to interpret what changes in these functions mean, it is recognised that some understanding of context is important. Thus work has been initiated using expert-based knowledge to identify limits for both the individual indicators and the aggregated land use functions for a set of 30 'Cluster Regions' across Europe (see Renetzeder et al., 2008), and to construct profiles describing the sustainability issues that are important within each region.

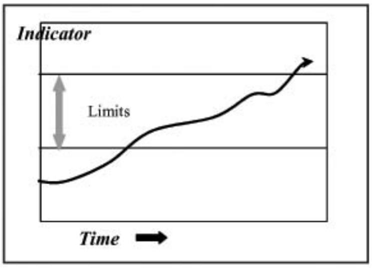
Implementation of the sustainability choice space concept will add a further dimension to this 'layering' of information in SIAT. As things stand by working with individual indicators and aggregated land use functions, the policy customer will gain insights into the potential impacts of particular policy options. A more rounded sustainability impact assessment will require a systematic comparison between various policy scenarios. In particular, users will need to develop an understanding of the ***sensitivity*** of the outcomes to different input assumptions, and the key points where different policy options may deliver different results. It is proposed that this type of analysis can best be provided using the sustainability choice space concept.

[11] See www.sensor-ip.eu

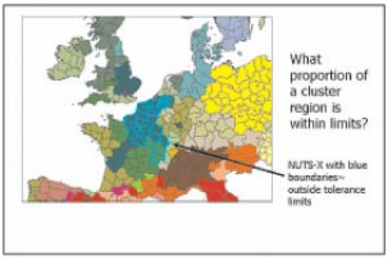
Figure 5 provides an illustration of how the idea of a sustainability choice space can be implemented as part of SIAT. Although the ideas have been framed around the specific needs of SENSOR, the issues are sufficiently generic to be of interest to those building other types of decision support system. The most important design requirements are that SIAT should:

- Allow users to identify those geographical areas that are most sensitive to particular policy scenarios, in the sense that projected policy outcomes potentially lie beyond specified economic, social and environmental limits, and to understand how outcomes differ ***between*** different policy scenarios. In this way the policy customer would be able to build up an understanding of the 'core' areas which might be impacted under any of the different policy options, and those where outcomes were more dependent on the policy choices made. The contextual information provided at Cluster Region level should be designed to help users understand what the key sustainability issues are in different areas, at least at the land use function level. For example, users should be able to compare the outcomes of the run of SIAT for the biofuel policy case, with assumptions of different world oil prices, and identify which areas are most likely to impacted under any circumstances, and which areas are more 'marginal', being sensitive to only particular sets of modelled assumptions.
- Allow users to identify how and where the broad impacts of different policy scenarios differ in terms of which indicator subsets or land use functions are affected and potentially driven outside specified limits. For example, it may be the case that under a given scenario one geographical region may mainly be affected by rising unemployment, while in another environmental damage might be an issue. The policy customer will need to understand where the 'pressure' points are for a particular scenario across the 'three pillars' and what policy choices are potentially available to resolve them.
- Allow users to look at any potential 'trade-offs' that appear to exist in a given geographical area or set of areas, in the sense that one particular policy scenario might affect the suite of indicators or land use functions in one way, while a second policy scenario might affect them in another. For example, users should be able to consider the outcomes of the biofuel policy case under assumptions of different levels of economic growth, and identify those situations where, say, growth in jobs might be offset by greater environmental damage, and those other areas where the reverse might occur.
- Finally, the system should allow the user to undertake all of the analyses suggested above 'dynamically', so that the trajectories of different

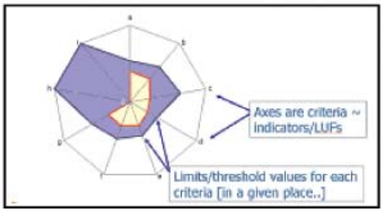
policy assumptions can be compared over ***time*** and space. For example, policy customers should be able to explore how differences between policy scenarios build up over time. If differences mainly only develop in the long term because of non-linearities, say, then given uncertainties the initial choice of policy option may not be so significant. Given the need to support decision making that is adaptive in character, policy customers should also be able to look at the effect of relaxing or changing particular constraints at some time in the future, to see if 'corrective' measures might be available should assumed trajectories not be realised.



The trajectories of individual indicators and/or land use functions can be plotted under different policy scenarios to determine the sensitivity of outcomes to different policy assumptions



At the NUTSx level, units where sustainability limits are exceeded for a given indicator or land use function can be highlighted. Limits may vary by cluster region (as indicated by the groups of coloured NUTSx unit). The proportion of units within a region that are sensitive to a given policy case can be used as a measure of the impact of a policy



Radar or spider diagrams can be used to show how outcomes impact across the set of land use functions (LUFs) for a given region and how limits differ for each of the elements. These diagrams can be animated to show how the situation changes over time.

Fig. 5. Implementing the Sustainability Choice Space Concept

The overall design requirement for SIAT, however, is that while the system attempts to map out the consequences of different policy assumptions, the user must not be misled into thinking there are 'optimal solutions' that can be identified by working with the system. The primary goal is to enable users to review the possible consequences of different policy assumptions and to understand how sensitive outcomes are on the basis of current knowledge. This issue is particularly acute in terms of the ways that ideas about economic, social and environmental limits are implemented and used within SIAT, and consideration of it brings us back once again to the question of how 'stakeholder knowledge' might be handled in SENSOR.

As Bertrand et al. (2008) have argued the specification of limits across the range of economic, social and environmental indicators that are included within SENSOR is a major task, involving many different types of uncertainty. While we have argued in this chapter that ultimately decisions about individual limits need to take account of all 'three pillars' and be grounded on an understanding of stakeholder values, practically this would be difficult to accomplish at European scales. Thus SENSOR may need to take an incremental approach.

The current work programme envisages that the specification of limits for indicators and land use functions will be based on 'expert knowledge'. This is a good starting point, but clearly the user must not be misled into believing these limits are 'definitive'. Thus at the most basic level SIAT users should be able to review what might happen if particular limits varied up or down by some margin - how would choices between policy options be affected? At the more sophisticated level, the policy customer would need to know how stakeholders might regard such limits and how their values might change them or affect the weighting between the different dimensions of well-being and environment captured by the land use functions. SENSOR is uniquely placed to explore this particularly important 'research frontier'.

A significant proportion of the resources supporting SENSOR have been given over to the analysis of stakeholder views and values (see Morris, 2008). This work can potentially give us insights about how, in particular geographical or problem contexts, people view the limits that 'experts' have suggested as being significant for individual indicators or the aggregated land use functions. Thus engagement with stakeholders can be used to help us understand how limiting values might need to be modified, and how trade-offs between the thematic areas covering the nine land use functions might be judged in different places. Engagement with stakeholders will also help us understand how *different groups* in society may vary in their responses. The 'contested' nature of economic, social and environmental limits needs to be conveyed in the design of SIAT.

While the primary goal of SIAT is to give an assessment of policies at pan-European scales, the availability of a rich body of information derived from stakeholders for particular areas and issues will allow the policy customer to explore how judgements may need to be modified where this richer body of information is available. The information gained from stakeholders through SENSOR for particular areas certainly ***cannot*** be extrapolated to other regions. However, the availability of such data can be used as part of the 'learning cycle' that both researchers and policy customers need to go through to move SIAT into the 'real world' where the 'democratisation of knowledge' is a pre-requisite.

By designing the SIAT in such as way that assumptions about limits can be examined, and values changed on the basis of expert and stakeholder views, a much richer and more flexible decision support environment can be created. If we can show how 'stakeholder views count' in particular places and for particular issues, future work may be initiated to extend the availability of this type of information to other geographical areas as part of a wider programme of stakeholder engagement.

7 Conclusions

Sustainability impact assessments are inherently difficult because they require policy advisors to compare things that are not easily compared. The concept of a sustainability choice space, however, provides a framework in which these complex types of judgements can be made. We have argued that decisions about the 'sustainability credentials' of different policy options do not depend on the search for optimal solutions. Rather, policy decisions are based on an understanding of the choices that we have available and the ways they are constrained by economic, social and environmental factors. If implemented within SENSOR, the sustainability choice space concept can lead to the development of a set of tools by which the different land use change trajectories can be compared, their impacts assessed, and the rationale used to make decisions set out in a more open and transparent way.

Acknowledgements

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Key sustainability issues in European sensitive areas – a participatory approach

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Abstract

This chapter describes the integration of stakeholder perspectives into the analysis of policy impacts within SENSOR. In particular, the chapter reports on a phase of 'extensive' research in selected 'Sensitive Areas Case Studies' (SACS), resulting in an overview of stakeholder perspectives on key sustainability issues. An understanding of these issues is presented as a critical reference point for subsequent research phases focusing on the impact assessment of land use policies. The discussion engages with one of the project's central preoccupations, namely, that the production of thorough-going policy impact assessments which describe changes in social, economic and environmental systems across European regions is limited by current modelling capacity and data availability. In response, SENSOR proposes to extend the analytical scope of the automated tools through participatory research in selected 'case study' regions. The results of this research will be made available to the end user through the SIAT user interface. Results of the early, extensive phases of participatory research are presented and some implications for the ongoing design and analytical extension of the tools are discussed.

Keywords

Participatory research, integration, stakeholders, communicative-rational, technical-rational, sustainability issues

1 Introduction

1.1 Integrated sustainability assessment

SENSOR sets out to produce tools for 'integrated' assessments of the sustainability impacts of land use related policies. Within the project, integration refers particularly to a 'Triple Bottom Line' (TBL) model of sustainability and, therefore, to impact assessments that reflect changes in economic, environmental, and social systems (Eggenberger & Partidário 2000, Sheate et al. 2003, Twigger-Ross, 2003). This is an ambitious undertaking in itself. However, the project also promises to integrate two apparently opposed approaches to sustainability policy science; one founded on an empiricist ontology and involving the systematic use of quantitative analyses of policy problems (Aguirre 1995, Weimer & Vining 1999) – which we refer to as the 'technical-rational' approach, the other founded on a relativist ontology which encourages a discursive approach to decision-making involving the participation of stakeholders (Majone 1989, Dryzek 1990, deLeon 1997, Fischer 1990, 1993, 1998), here referred to as the 'communicative-rational' approach. The integration of technical-rational and communicative-rational approaches is evident in the interdisciplinary nature of the SENSOR project team and in the overall project design where colleagues from the natural, economic, and social sciences are working closely together on research activities and project outputs. This chapter presents some preliminary findings of communicative-rational research in the project's case study areas and looks forward to how this work will be integrated into the design of the tools.

SENSOR has a central and defining logical framework, based around the OECD's Driver-Pressure-State-Impact-Response framework (OECD 1998, 2000, 2001). Within the context of SENSOR the framework is applied as follows: the end-user (policy-maker) generates policy scenarios. New economic, fiscal, or legislative conditions arise from these scenarios which, thereby, act as drivers of land-use change. The pressures are the predicted changes in land use and management. States are reflected by changes in social, environmental and economic systems as evidenced by indicators. Sustainability impacts are assessed by comparing indicator value changes against sustainability thresholds and targets. The responses, or the decisions taken in light of the assessment, are the prerogative of the end-user. Taken at face-value this logical framework seems to belong squarely with proponents of a technical-rational approach to policy science, based as it is on assumptions about a simple, linear causality where elements of the system react in predictable ways to changes that occur 'upstream'. There is much evidence to suggest, however, that human-nature systems are much more complex than this logical framework implies. Often policies are applied and, crucially, interpreted differently by practitioners operating in different contexts, sometimes with unforeseen and surprising consequences (Waterton et al., 2006). Furthermore, along with any change in policy there is likely to be a number of socio-economic and biophysical forces that will influence the impacts of land-use changes. However, the logical framework described above is not the whole picture. Faced with the complexity of the human-nature systems it sets out to analyse, SENSOR acknowledges the inherent limitations both of its own central logic, and of the modelling capacities it seeks to develop. This recognition is written into the project design in the form of provisions for participatory processes and stakeholder-inclusive research aimed at engaging critically with both the analytical scope and the outputs of the tools produced. By throwing together technical-rational and communicative-rational approaches to sustainability science under one project, SENSOR aligns itself with the criticisms in policy analysis literature of those commentators who are preoccupied with presenting a somewhat sterile opposition of so-called ‘positivist’ and ‘post-positivist’ camps and who fail to reflect the willingness and capacity for open, reflexive and collaborative science that characterise many policy-oriented research activities (Durning, 1999).

SENSOR’s attempt at integration is, in part, driven by the results of the institutional analysis work (see Thiel and König, 2008; Tabbush et al., 2008), which expose the diverse institutional contexts and conditions in which impact assessment work is conducted. Depending on the policy under examination, and on the time, resources and data available, impact assessment is sometimes a ‘quick and dirty’ process involving crude analyses of limited data. Under different conditions, however, assessments may involve a long and painstaking process of data- and insight-gathering, followed by detailed analysis involving numerous partner organisations and individuals. In response to this complex institutional environment, SENSOR sets out to produce a range of tools and approaches from which end-users can select and adapt according to their needs. These tools will result from model, model interface and database development over the course of the project, and this development will be continually informed by stakeholders through various participatory research processes. In this way, and alongside the automated Sustainability Impact Assessment Tool (SIAT), SENSOR hopes to provide mechanisms that may be used for further engaging European citizens themselves in the complex business of assessing the sustainability impacts of European land use policies. This will be done, not only by presenting the results of participatory research through the SIAT user interface, but also through the elaboration and development of stakeholder-inclusive research methodologies that may be put into practice by policy-makers in the future.

The early development of these participatory research processes provides the main focus of this chapter.

1.2 The need to involve stakeholders

At present, the scope of SENSOR's orientation to sustainability impact assessment is defined by the social, environmental and economic 'Impact Issues' set out in the European Commission's 'Impact Assessment Guidelines' (CEC, 2005)[1]. From these Impact Issues project partners are selecting those that are likely to be affected by land-use related policies. In turn, for each relevant issue, a list of indicators is being generated, based on a consideration of data availability and the capacities of the macro-economic, sectoral and cross-sectoral models that provide inputs into the SIAT. However, there is general acceptance that SENSOR should be ambitious and innovative in trying to find ways round the problems of limited data availability and modelling capacity; sustainability issues exist whether or not we have the data and models to analyse them. As such, while the data driven analysis is useful, and is the central design focus of the automated modelling tool requested by the European Commission, detailed stakeholder-inclusive research can add to the analytical scope of the project by identifying the limitations of a mechanistic, data-driven approach, and by indicating where additional capabilities need to be developed.

In addition, while the issues listed in the Guidelines and the core set of indicators generated within SENSOR provide a useful starting point for our analysis of policy impacts, there is general agreement amongst partners that many European regions are facing complex land-use related issues and problems which will fall outside their scope. Of particular relevance here is the issue of complexity and the fact that comprehensive sustainability assessments require the simultaneous analysis of the relationships between environmental, economic and social issues in order to assess policy impacts accurately and in order to inform decisions about unavoidable trade-offs, compromises and possible win-win situations:

'...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 particu-

1 Go to: www.eu.int/comm/secretariat_general/impact/docs/SEC2005_791_IA%20guidelines_annexes.pdf

larly true if the interrelations between the three pillars are not adequately understood and described...' (Gibson 2001: 12).

Furthermore, as discussed above, assumptions about a simple, predictable and causal relationship between changes in policy and the social, environmental and economic responses to that change have often proved to be wrong (Waterton et al., 2006). Policies are never likely to be the only drivers of change and attempts to analyse their effects in isolation will always be problematic. However, interdisciplinary, stakeholder-inclusive research of the kind proposed within SENSOR can contribute here by usefully complicating the analysis of policy impacts, 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 at the outset. In short, the assumption that researchers can define the scope of analysis in advance can be usefully challenged through stakeholder processes by forcing an engagement with questions relating to whose knowledge and whose expertise counts (Collins and Evans, 2002; Wynne, 2003; Jasanoff, 2003), whose definition of the problem is expected to remain stable, and whose has to shift, or how an agreed common framing of problems and potential solutions can be reached.

In a general sense, the analysis of sustainability issues through participatory research hopes to perform a revelatory function within the project, by highlighting a range of context-specific issues that should be factored into an analysis of policy impacts, and by providing insights, through a critical engagement with project methodologies, as to how these issues might be best accommodated within the analytical functions of the tools and methodologies developed within SENSOR. Behind this proposed revelatory function lies an acknowledgement of the necessary limitations of a participatory analysis of land-use futures. Stakeholder perspectives are not being sought in an attempt to provide definitive predictions of sustainability impacts across European regions that will replace, or veto the predictions of the SIAT – to do this would be to give a false impression of consensus, uniformity and accuracy in relation to issues which, in reality, are often highly diverse, complex and contested. Rather, the aim is to provide a means of bringing the diversity of opinion relating to a given issue to the attention of policy- and decision-makers in Brussels – to highlight and support, rather than to resolve public debate. Furthermore, by adopting an exploratory, revelatory, rather than an overtly instrumental approach, project partners hope to avoid using processes of stakeholder involvement to provide an illusory public endorsement of professional agendas and visions

– a tendency which has been highlighted in critiques of participatory development discourse and practice (see especially Cooke & Kothari, 2001).

SENSOR's participatory research framework and its envisaged exploratory role in the overall project has been a feature of earlier integrated projects funded by the European Commission (see, for example, Kasemir et al. 2003). The approach also has strategic relevance, with the Commission itself being committed to an inclusive approach to developing and implementing policies, as outlined in a recent Communication (EC 2002). However, consultation as it is practiced by the Commission tends to play a much more instrumental role in the policy-making process. For example, the Communication states that the involvement of interested parties stands to improve the quality of a policy outcome by ensuring that its proposals are technically viable, practically workable and based on a bottom-up approach. This instrumental function is also reflected in the Impact Assessment Guidelines, where the consultation of interested parties, which figures as one of the procedural rules governing the impact assessment process, can usefully inform all six of the key analytical steps involved (Tabbush et al., 2008)[2]. Examples of participatory input into impact assessment are the 'Advisory bodies' (composed of experts sent by Member States or interest groups) set up and run by the DG in charge of the relevant policy field, the SINAPSE e-network used for consulting experts, sectoral consultation procedures involving panels of business representatives, and the Interactive Policy Making Initiative where online questionnaires are sent to experts and interest groups.

1.3 The need for case studies

Behind the SENSOR approach to developing a Sustainability Impact Assessment Tool (SIAT) lies the recognition that different European regions are facing different types and intensities of sustainability issues. For example, post-industrialised regions, often characterised by high levels of unemployment, deprivation and environmental contamination, represent particular challenges to any assessment tool supporting policy decision-making with a Europe-wide application. Because the SIAT will be expected to assess the impacts of land-use related policies against criteria of sustainability that are appropriate not only at European, but also at regional

[2] The six 'Key analytical steps in impact assessment' are: 1. Identify the problem, 2. Define the objectives, 3. Develop main policy options, 4. Analyse their impacts, 5. Compare the options, 6. Outline policy monitoring and evaluation (CEC, 2005) 791, p.4). The SENSOR project is charged with producing tools (SIATs) which will be used during step 4.

and local (down to NUTSX) levels, this heterogeneity of sustainability issues demands that specific sensitivities be built into the design of the SIAT. Based on this recognition, SENSOR partners are carrying out research into sustainability issues in so-called ‘sensitive areas’, made up of Europe’s mountain, island, post-industrial and coastal zones

This research is conducted at two spatial scales. Firstly, through consultation with key experts, partners are carrying out an extensive pan-European survey of sensitive areas. These surveys, which also include the clustering of sensitive areas, provide the basis for environmental and socio-economic profiling with the aim of identifying relevant and important variables for sustainability assessment. The aim of the work at this spatial resolution is to produce a generalisable list of sustainability issues for each sensitive area type in its wider regional setting. Secondly, from within these sensitive areas, representative sustainability ‘hot-spots’ have been identified for more intensive research. These are referred to as the ‘Sensitive Area Case Studies’ (SACS)[3] and it is here that project partners are conducting detailed research into context-specific sustainability issues. Firstly, available data related to local sustainability issues is gathered and used to validate tool outputs (Dilly et al., 2008). Secondly, project partners are engaging with regional and local stakeholders to produce finer resolution analyses of sustainability issues. Thirdly, and as a complement to the data-driven validation, stakeholder-inclusive research in the SACS is also used to test model outputs and to inform subsequent adjustments. The use of both data-driven and stakeholder-inclusive approaches to SIAT validation means that the integration of technical-rational and communicative-rational approaches to impact assessment is also evident in the case study research.

2 Stakeholder-inclusive research methods

The sustainability impact assessment tools in SENSOR are being developed to a broad and challenging brief. The European Commission has requested tools which can be used to assess the impacts of policies relevant to a total of six land-use sectors.[4] Furthermore, SENSOR proposes a suite

[3] The SACS chosen for the SENSOR project are: The Maltese Archipelago (Malta), Eisenwurzen (Austria), The High Tatras (Slovakia), Silesia (Poland), Western Estonia Coastal Zone and Saaremaa Island (Estonia), Valais (Switzerland), Saxony Lusatia (Germany).

[4] SENSOR deals with six land use sectors, namely, nature conservation, tourism, transport, agriculture, forestry and energy.

of tools that can predict sustainability impacts across European regions. Logically, this means that the tools must reflect a potentially wide range of sustainability issues and criteria. This broad remit poses a particular methodological problem when it comes to stakeholder-inclusive research, because there is rarely a single, bounded research problem which allows the selection of stakeholders and the definition of research questions from the project's outset. Rather, stakeholder analysis and problem definition must be specific to individual policy cases and each case study location. As such, an iterative research approach is required, involving the case-by-case analysis of issues and stakeholder selection. This unfolding process of refining and broadening issues in the light of engagement with an expanding list of stakeholders and policies means that knowledge of each SACS is built up over the duration of the project.

However, even an iterative research approach needs a starting point – a phase of data- and insight-gathering which provides a knowledge base informing and directing subsequent, more targeted, research phases. In each of the SACS, the starting point was a period of extensive research, involving 'quick-scan' profiling of sustainability issues and the stakeholders associated with those issues. This profiling work involved mostly desk-based research, a number of scoping interviews with key stakeholders identified by the project partners representing each SACS and, in some cases, the use of focus groups. The results of this extensive research are presented in profile reports for each SACS, which contain information on geography, history, demography, economy, existing European policies and funding, key sustainability issues and a broad stakeholder analysis. These reports formed the basis for early project deliverables and will be displayed as information notes within the SIAT tool. Some results of this extensive profiling phase are discussed in the paragraphs that follow.

This extensive research phase provides the information base for intensive stakeholder-inclusive research based around actual policy cases – work that is currently underway at the time of writing. In particular, the profiling work enables us to establish the connections between stakeholders (groups and individuals), sustainability issues, and policy areas, providing a basis for stakeholder selection and a starting point for discussions.

The analysis of policy cases with stakeholders is structured around the analytical steps performed by the SIAT, which in turn reflect the logical framework of the overall SENSOR project:

(1) policy changes that are likely to result in changes in land-use; (2) land-use claims are postulated; (3) through the resulting changes in land-use, but also through other pathways, these policy changes will lead to changes in social, environmental and economic systems, which will be represented by specific indicators; (4) an assessment of what these changes mean for

sustainability will then involve the comparison of these changes against thresholds and targets.

These analytical functions provide the structure for the work with stakeholders, giving rise to four research phases:
(1) The examination of national and regional interpretations and implementations of the policy and the exploration of the perceptions of sustainability issues behind them; (2) An assessment of the impacts, in terms of changes in land-use, of the proposed policy; (3) An assessment of the impacts of the proposed policy on social, economic and environmental sustainability indicators; (4) The assessment of the sustainability of these impacts through the elicitation of trade-offs and the identification of the Sustainability Choice Space (Potschin and Haines-Young, 2008) through comparisons with limits. Although the approach is linear, with each phase of research delivering information and insights providing the starting point for the next phase, participants in one workshop are able to revise their views from previous workshops (but not change the overall methodology).

Both research design and the selection of stakeholders are tailored to the specific requirements of each of the four phases. Phase 1 involves the use of semi-structured interviews with policy-makers operating at national level and responding to EU policy directives and targets. These are typically representatives of competent government departments and members of the working groups and advisory panels set up to assist with the policy design process. Phase 2 involves a variety of methods, including semi-structured interviews and discussions, with the analysis of land-use change in the case study area itself requiring the selection of stakeholders at regional level. These are typically people who work in the regional offices of government departments, those involved in spatial planning and decision-making, representatives of relevant land-use sectors, and in some cases, landowner interest groups and associations, and landowners themselves.

The analyses of impacts and sustainability limits (Phases 3 and 4) are conducted in stakeholder workshops and involve a number of research methods. The workshops involve the presentation, discussion and refining of national policy scenarios and their regional land-use change implications, based on the results of Phases 1 and 2. Drawing on the results of the profiling work, a list of relevant sustainability criteria are then discussed, refined and scored (using a simple scoring system). Criteria scores are then discussed. Next, a list of key sustainability indicators is drawn up and these are then used as the basis for an impact assessment for each policy scenario. After a group discussion of the results of the impact assessment procedure, the issue of limits is addressed through a group discussion of the acceptability of the predicted impacts.

While consensus within the group is sought at various points within the workshops (the selection of policy scenarios, the selection of criteria, criteria ranking by calculating score averages, the selection of key indicators, the assessment of impacts by calculating average impact scores, determining the acceptability of impacts), it is never imposed. Differences of opinion which cannot be resolved through discussion are recorded. Furthermore, while average scores for criteria and impacts are calculated, individual scores are also recorded. Where there are big differences in the scores given by individuals, these then provide the basis for further discussion. In this sense, the scoring exercises are not used to produce falsely consensual ‘results’, but themselves become a component of a deliberative methodology designed to tease out and explore a range of opinions relating to a given issue.

3 Early research results

As stated earlier, the time of writing coincides with the completion of the profiling work in the SACS. As such, only the results of the profiles are currently available for presentation and discussion. These extensive studies of sustainability issues in the SACS have yielded some useful insights during the early stages of SENSOR that were used to problematise aspects of the project’s conceptual framework. In the paragraphs that follow, some key sustainability issues in one of the SACS (Malta) are presented, and are accompanied by information gathered during the profiling phase (see Moncada & Camilleri, 2007), which helps to set each issue in its wider land-use and policy context.

The key issues emerging from the profiling phase, namely, high population density, land use and development, and use of natural resources can be seen as a kind of ‘nexus’ in the sense that they represent a set of closely inter-related sustainability problems currently faced by Malta (Moncada & Camilleri, 2007). It is this inter-relatedness of problems which poses a particular challenge to IA procedures premised on the use of sustainability indicators which are grouped under the social, economic and environmental headings of the three pillars of sustainability. This organisation of indicators, unless carefully managed, runs the risk of erroneously treating as separate social, economic and environmental issues which are in fact closely inter-related and inter-dependent. As will be seen, a change in the status of one issue will have knock-on effects on others. It is this inter-relatedness of issues that highlights the artificial nature of the conceptual boundaries between social, economic and environmental processes implicit in the TBL approach, demanding close critical scrutiny of impact assessment procedures and results and careful consideration of how the results of analysis are presented to the policy-maker.

3.1 Sustainability issues in Malta

Based on the findings of the profiling work and on the results of interviews and focus groups with Maltese stakeholders, one complex, or 'nexus' of sustainability issues emerged as particularly significant. At its heart are the issues of high population density, land use and development, and use of natural resources.

High population density: During focus groups and interviews, stakeholders expressed concern about over-crowding and feeling surrounded by people and buildings. Malta is very densely populated. In 2005 population density reached 1,279 inhabitants / km², compared with an EU-25 average of 117.5 / km² (in 2003) and an average of 182 inhabitants / km² for European islands. Problems associated with a high domestic population density are compounded by the 1.2 million tourists that visit the islands every year. The number of beds available for tourists has grown from 1,200 in the early 1960s to 39,444 beds in 179 establishments by February 2006. The majority of accommodation premises are found along the coast, particularly in St. Paul's Bay, Bugibba, Qawra, St. Julians, and Paceville. Other major tourist developments are focused in Sliema, Gzira, Msida, and Valletta / Floriana. Since some development occurred within residential areas, conflicts between users resulted in the out-migration of residents. This mainly resulted in a shift of population from the Inner Harbour area to the Outer Harbour area with the construction of new homes.

Land use and development: land use and high rates of property development are the basis for major concerns within the Maltese islands. The Islands have a high urbanization rate, standing at almost 22 percent of the total land area. A useful indicator of construction activity in the Islands may be found in trends in dwelling units granted planning permission. The number of units permitted grew by 162% between 2000 and 2006, in contrast with population, which increased by 3.6% during the same period. The high level of activity in the property market has a direct effect on consumption of land resources, mineral resources in the form of stone extracted from quarries, and land take-up, especially on the coast and the countryside, also affecting the overall recreational space available. As a consequence of the expansion of the property market, prices for housing have risen considerably, making the purchase of properties for first time buyers more difficult. This directly affects the liquidity of the younger generation and might undermine the overall diversification of investments towards other economic and financial opportunities. However, the construction industry plays an important economic role, representing 6.9 percent of total employment[5], and providing a contribution of 5.2 % to the total Gross Domestic Product (GDP) in 2006.[6]

Use of natural resources: natural resources are significantly affected by land use and development. Malta's key mineral resource (limestone) is the primary input for the construction industry, but its market price does not reflect its scarcity, making it easier to extract and consume. Most land development has an effect on another natural resource - biodiversity, particularly in coastal and urban fringe areas. This can happen either directly through alteration, fragmentation and loss of natural ecosystems, habitats or species, or indirectly through increased interference with environmental media such as air, soil and water, including light and noise pollution. In addition, building development in valleys and 'floodplains' has a direct effect on the water system, with less water being absorbed into the water table, putting more pressure on the scarce natural reserves, and also increasing the risk of flooding.

3.2 Early lessons for SENSOR:

The nexus of inter-related sustainability issues in Malta described above has important ramifications for SENSOR's proposal to produce tools for 'integrated' sustainability assessments, as discussed in the introduction. Although any assessment of sustainability which incorporates all three pillars represents a significant challenge in itself, the extent to which the analysis is truly integrated depends on different definitions of the term. In terms of integrating the three pillars, SENSOR proposes to go beyond existing assessment frameworks based on 'strong' and 'weak' definitions of sustainability (Neumayer 2003). Under the principles of 'strong' sustainability, where the reduction of any resource below defined thresholds is unacceptable, integrated assessments consider the social, economic and environmental impacts of a policy. However, these figure as separate calculations in the analysis. Similarly, under 'weak' sustainability, where the reduction of one resource is acceptable if it is compensated by a gain in another, integration merely requires an analysis of the net impact on the three pillars. Again, measurements of increases and reductions in eco-

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[5] NSO (2006).This figure is made-up of both full-time and part time employment, whereas full-time employed represents 8.12 percent of the total employment.
[6] NSO (2007).

nomic, environmental and social resources occur as distinct phases in the analysis. Judging the sustainability of a proposal is then a matter of determining whether these increases and reductions are acceptable through comparisons with the thresholds and limits associated with individual indicators. The limited extent of integration permitted under strong and weak definitions of sustainability points to the false notion that environmental, economic and social phenomena can exist somehow independently from one another, and that changes in one resource can occur in isolation from changes in another. Under these definitions, sustainability is thought of as the sum of its constituent (economic, social and environmental) parts (Gibson 2001).

Malta's land use-natural resources-population sustainability complex, however, reveals the extent to which environmental, economic and social phenomena are intricately bound together, making it problematic to try to analyse impacts on separate phenomena and then to assess the net effect. For example, Malta's fragile biodiversity and natural resources, already threatened by high population density, are also under threat by land development, which in turn increasingly tends to occur in sensitive areas, rich in biodiversity and landscape value. However, economic growth in Malta also depends for a considerable part of its GDP upon the role of the construction industry and property markets (including banks, insurance companies and financial operations). This means that policy decision-making will involve difficult decisions about priorities and any trade-offs. If we acknowledge the inter-causality of issues within this complex, it follows that any isolated analysis of a policy's impact on, say, percentage of land built up will be of limited value, even if the analysis goes on to consider impacts on natural resources and population density. Integrated sustainability assessment must explore the inter-relations between all the issues implied by the complex and related to the policy under analysis (Post et al. 1997, Eggenberger & Partidário 2000, George 2001). In the words of one commentator:

'the combined impacts, positive and negative, of the sets of measures as a whole, are likely to be more than the simple sum of the impacts of their constituent measures because of synergistic effects' (Lee & Kirkpatrick 2001, quoted in Pope et al. 2004).

The challenge of modelling integrated sustainability impacts is met in SENSOR through the development of accessible, multi-dimensional tables or 'decision trees' which represent the relationships between model functions and datasets, using simple mathematical procedures that are visible to the end-user through the SIAT interface. The results of stakeholder-inclusive work conducted in the SACS, of the kind discussed above, indicate that our ongoing research can usefully inform and shape the progress of this ‘functional analysis’ by providing insights into the relationships between issues and their corresponding indicators as they apply to a policy change in a case study setting. This is not to say, however, that the insights gained through participatory research will be in any way privileged above other forms of knowledge within the project - the role of participatory research is not to produce definitive representations of system dynamics that will be used to over-ride or trump model-based analyses. Rather, it is recognised that, just as with other knowledge forms, stakeholder perspectives can be partial, subjective and conflicting. As such, the participatory research conducted in the SACS merely aims to present alternative accounts of how system dynamics might change in response to policy drivers, allowing policy makers to make more informed policy decisions based on critical interpretations of model results.

By way of an example, let us imagine that Europe is proposing a new biodiversity policy, which encourages government to put additional areas under environmental protection and farmers to shift from harmful agricultural practises to more sustainable ones. This policy might lead, in the context of Malta, to larger areas being excluded from potential land development and with agricultural activity screened more carefully for its environmental impact. Under strong and weak definitions of sustainability, an integrated assessment of the impacts might involve a calculation of the likely increase in biodiversity (environmental impact), the employment effect of a change in agricultural practices (social impact), and the change in the sectoral share in GDP (economic impact). Through the use of environmental economics, a common metric (monetary) might be applied to all these resources and the net effect or impact of the policy could be calculated, and a decision about the sustainability of the policy reached. However, stakeholder-based analyses of the same policy would highlight the fact that the environmental, economic and social impacts of changes in land use driven by a biodiversity policy will not be limited to the agricultural sector, but will also affect other economic activities such as construction industry and tourism. Some stakeholders might highlight the fact that increased protected areas and environmental friendly agricultural practices by farmers will mean an increase in tourism. Others may argue that due to the drive for environmentally-friendly agricultural practices, the overall production might decrease, with the risk of abandonment of agricultural land by farmers, and a consequent reduction in agro-biodiversity. Coming from a different perspective, others may argue that a reduction in the number of tourist facilities in high landscape value areas might undermine Malta's capacity to compete in the international tourism market.

The example above goes some way to illustrating how supplementing model- with stakeholder-based analyses can provide a more informed basis for policy decision-making. In this case, difficult choices would have to be made in relation to the necessary trade-offs between employment and revenue gains and losses in the agricultural and tourism sectors, together with the wider social and environmental losses and gains implied by different policy scenarios. In other words, stakeholder-based analyses are well placed to provide more integrated impact assessments, reflecting the functional relationships between the different sectors and the different complexes of issues implied by the policy under examination – in this case agriculture, tourism and construction and the complex of issues centred around biodiversity, population density, resource scarcity and landscape aesthetics. In this way, assessments of the sustainability impacts of a given policy can be broadened out to capture what Post et al. (1997) refer to as:

'the three (economic, social and natural) subsystems and their intersystem relations'.

While technical-rational approaches to impact assessment might be useful in terms of presenting a rough estimation of how different resources will be effected by a change in policy, ultimately analyses of the broader implications of policy change enabling the definition of the relevant 'sustainability choice-spaces' (Potschin and Haines-Young, 2008) should involve the people affected by the decisions that come out of those analyses – they should involve communicative-rational impact assessment methods of the kind being developed in the SACS.

4. Conclusions and next steps

This chapter gives an overview of the analysis of sustainability issues through stakeholder-inclusive research in the SACS. Emphasis is given to demonstrating the value of stakeholder-inclusive research within the SENSOR project inasmuch as it provides a mechanism for exploring the wider functional relationships within and between the sustainability issue complexes implicated by a given policy change. Using a specific example of a complex of key issues highlighted through research in Malta, attention is drawn to the synergistic relationships between impacts on resources under the three pillars of sustainability. Similarly, the cross-sectoral effects of a hypothetical sectoral policy are demonstrated. It is in this capacity that the research's key contribution to achieving SENSOR's objective of producing tools for integrated sustainability impact assessment is demonstrated.

However, beyond analyses of the cross-sectoral implications of new policies and the inter-relationships between social, economic and environmental impacts, 'integration' takes on additional significance within the context of the inter-disciplinary research project, SENSOR. Here, a further requirement in terms of integration is that the insights gained through a deliberative research approach involving stakeholders must be closely related to, feed into, and somehow allow critical engagement with the insights gained through model-based analyses. The need for this additional form of integration has been discussed earlier in this chapter where the limitations of model-based analyses of sustainability impacts expressed in terms of the net effect of policies on stocks of social, environmental and economic resources were highlighted. There it was argued that complementing model-based with stakeholder-based analyses would maximise the potential to usefully complicate the analysis, bringing details of the inter-relationships and inter-dependencies between a complex of pertinent issues to the attention of the policy-maker – i.e. the discussion referred in the main to integration across sectors and between impact types, not to integration across methodological and epistemological boundaries. A further task, however, is to integrate technical-rational (model-based) with communicative-rational (stakeholder-based) analyses of policy impacts, requiring ever-closer collaboration and inter-disciplinary working.

The need for both forms of integration presents a significant challenge, not least because each places particular demands on the research, both in terms of methodological approach and data type. Integrated analysis across the three pillars of sustainability and between sectors, shedding light on complexes of sustainability issues, requires a deliberative research approach allowing stakeholders representing a range of interests to explore the wider implications of a policy change. The results of this analysis will be predominantly language-based, qualitative and relational. The need to integrate the results of stakeholder deliberations with model-based analyses of policy impacts, on the other hand, requires a much more tightly structured approach where stakeholders are asked to give more precise predictions of policy impacts using indicators. The results of this analysis will be predominantly quantitative and reductionist. By proposing to integrate communicative-rational (stakeholder-based) with technical-rational (model-based) analyses, in spite of their appearance as uncomfortable methodological and epistemological bed fellows, SENSOR seems to be proposing to have its analytical cake and eat it.

Despite the challenging nature of this task, however, the research currently underway marks another significant step towards more integrated (in both senses) analyses of policy impacts. At the time of writing, project partners are engaged in an intensive period of participatory research in the SACS aimed at validating model-based assessments of policy impacts. This iteration of stakeholder research is structured around SENSOR's logical framework, giving rise to four, linked phases of stakeholder research (discussed above). A fundamental and disciplining influence over the design of this research has been the need to achieve a balance between the opposing demands of our two forms of integration (outlined in the previous paragraph). A realisation of the need for this balance has emerged in parallel with the need to define what is meant by validation, based on a careful consideration of what is realistic in terms of stakeholder-based analyses of policy impacts. Under a conventional approach to validation one might expect stakeholders to provide precise predictions of changes in sectoral claims over land, precise predictions of impacts expressed in terms of changes in indicator values, and the precise setting of limits allowing measurements of the distance from sustainability implied by the impacts driven by a change in policy. However, the fact that stakeholders are unlikely to be able to offer this level of precise quantification (the connection between a policy and its impacts is just too complex) is actually an advantage in terms of achieving the two forms of integrated analysis outlined above because it forces a research design which recognises the need for both precise quantification and discursive exploration.

The need for this balance between quantification and exploration has caused SENSOR partners to re-define the objective of the participative research, less in terms of 'validation' and more in terms of 'ground-truthing' the predictions of the models. So, rather than spatially accurate predictions of land-use change, stakeholders are asked about those regional factors relating to land management which determine and constrain landowner and tenant responses to policies. This information can then be used to highlight any glaring errors in the model-based forecasts caused by a lack of information or understanding about local geophysical and socio-political factors. Similarly, rather than precise predictions of indicator value changes, stakeholders are asked to forecast negative or positive impacts on a simple scale, taking into account the relationships between different sectors and between social, economic and environmental factors. Both the discussions and the impact scores arising from this task provide a basis for critical engagement with model outputs. Finally, rather than asking stakeholders to set precise limits for different impacts, they are asked to discuss the acceptability of impacts in the light of their knowledge of the current status of different resources and land-use functions. Stakeholder-based assessments of the acceptability of impacts can then be compared with the threshold settings within SIAT.

By facilitating a combination of stakeholder-based discussions and quantified impact assessments of policy scenarios, this research design sets out to achieve a balance between the conflicting demands placed on it by our two forms of integration – one requiring the purposeful complication of the analysis, the other requiring its simplification. In the light of this careful balancing, and in response to positive encouragement from the European Commission, it is envisaged that, in addition to the more tangible results of stakeholder-based validations of model-based analyses, a major output of the SENSOR project will be the delivery of participatory methodologies and tools that can be further developed with the aim of increasing the involvement of multiple publics in the process of sustainability impact assessment, thereby significantly enhancing the deliberative scope of European policy-making.

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Key sustainability issues and the spatial classification of sensitive regions in Europe

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Abstract

Cross-cutting environmental, social and economic changes may have harsh impacts on sensitive regions. To address sustainability issues by governmental policy measures properly, the geographical delineation of sensitive regions is essential. With reference to the European impact assessment guidelines from 2005, sensitive regions were identified by using environmental, social and economic data and by applying cluster analysis, United Nation Environmental Policy priorities and expert knowledge. On a regionalised 'Nomenclature of Territorial Units for Statistics' (NUTS) level and for pre-defined sensitive region types (post-industrial zones, mountains, coasts and islands) 31 % of the European area was identified as sensitive. However, the delineation mainly referred to social and economic issues since the regional data bases on environmental indicators are limited and do not allow the separation of medium-term vital classes of sensitive regions. Overall, the sensitive regions showed indicator values differing from the EU- 25 average.

Keywords

Coasts, European policy, impact assessment, islands, mountains, post-industrial zone, sensitive regions, sustainability impact assessment

1 Introduction

The European Union consists of 27 member states in 2007 and covers with 4.2 billion km^2 about 40 % of the European continent. Each country of the European Union has its specific history and culture and national governments range from centralised to federalist regimes. The physiographic European Union includes gradients from arctic to Mediterranean, maritime to continental climatic factors and altitudes from sea level to mountains of about 4500 m above sea level. In 2004, the population density was 118 people per km^2 in the European Union (European Commission 2004) compared with 96 people per km^2 in the entire European continent and 30 people per km^2 in the U.S.A. The uses of land for agriculture, forestry, nature conservation, tourism, energy and transport compete for limited natural resources and strongly influence the environmental, social and economic conditions. These land use types are addressed in the EU Integrated Project 'Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions – acronym SENSOR'.

Impact Assessment is now a requirement for EC policy initiatives (Tscherning et al., 2008), and the European Commission published impact assessment guidelines in 2005 (CEC 2005). The guidelines separated five key analytical steps: (1) Identify the problem, (2) Define the objectives, (3) Develop main policy options, (4) Analyse their impacts, (5) Compare the options and (6) Outline policy monitoring and evaluation. SENSOR covers steps 4 to 5. The impact assessment guidelines identified 11 economic (ECON), 9 social (SOC) and 12 environmental (ENV) "impacts", and this analysis has formed the basis for indicator selection within SENSOR (Frederiksen and Kristensen, 2008).

To carry out impact assessment of policy options at European level, regional knowledge is essential. The Nomenclature of Territorial Units for Statistics (NUTS) is a standard for referencing the administrative division of countries for statistical purposes. The standard was developed for the European Union, and thus only covers the member states of the EU in detail. NUTS0 refers to the entire country, NUTS1 level to the next subdivision of states or group of states and NUTS2 and NUTS3 to regions, provinces and counties. SENSOR focuses on a combination of NUTS2 and NUTS3 levels, here called NUTSx level, in order to identify regional scale in addressing both policy options and key issues. Renetzeder at al. (2008) has distinguished 581 NUTSx cells for the EU-27 based on the reference grid of EEA and the European Geo-Portal INSPIRE standards (JRC 2007).

The policy makers at the European Commission need to identify, through Impact Assessment, if there are regions in the member states where policy measures might have unintended and unsustainable consequences, as a result of local conditions. Those regions can be defined as "sensitive". They will differ from regular European NUTSx cells due to their vulnerability regarding environmental, social and economic sustainability issues. For example policy cases to increase the share of bio-energy, to stimulate the preservation of bio-diversity and to strengthen the common agricultural policy may induce cross-cutting conflicts. Such potentially sensitive regions were pre-identified as post-industrial zones, mountains, coasts and islands in Europe, and part of SENSOR's work was to identify these geographically and then arrange them into categories or types, based on specific sensitivities. Special attention was given to new member states of the EU. SENSOR works at EU-27 + 3, to include Iceland, Norway and Switzerland.

The objective of this paper is to summarise the methodology for the analysis of sensitive European regions based on (i) the pre-definition of sensitive region type, (ii) the analysis of free data-bases on sustainability issues and (iii) the application of the European impact assessment guidelines.

2 Materials and Methods

Steps for location and key issue identification

The generation of the overview of sensitive regions followed 10 steps:

1. Geographical identification of Europe's potentially sensitive post-industrial zones, mountains, coasts and islands, preferentially at the SENSOR NUTSx (here between NUTS2 and NUT3) spatial level,
2. Literature review to identify sustainability issues and data sources, e.g. CORINE land cover (CLC), EUROSTAT and EEA reports,
3. Assessment of secondary data availability and the evaluation of the necessity of collecting primary data,
4. Data collection on key issues in sensitive areas, based on the impact issues identified by the European Impact Assessment Guidelines,
5. Consultation with relevant stakeholders with regard to their view on sustainability issues in sensitive regions throughout Europe,
6. Simple web-based questionnaire to collect qualitative and (semi)quantitative assessment data on key sustainability issues,
7. Statistical analysis and clustering of sensitive regions based on available indicators to create classes of post-industrial zones, mountainous regions, coastal areas and islands with similar environmental, social and economic characteristics,
8. Generation and interpretation of maps with key issues of sensitive areas,
9. Drafting of four sub-survey reports, and compilation into a final report for the 4 sensitive areas types in SENSOR,
10. Integrated and comparative analysis of key sustainability issues across sensitive area types and against a standard, e.g. European average.

Post-industrial zones

The spatial density of industrial sites within a single NUTSx cell for EU-27 based on the CLC 2000 land cover layer was used to identify post-industrial regions. Three classes of industrial sites were separated: (1) combined industrial and commercial sites, (2) dump sites and (3) mineral extraction sites.

Proxy identification of post-industrial sites was extracted from CLC 2000 using a 5 x 5 km moving window. Extraction of post-industrial areas from industrial and commercial classes was based on the assumption that historical sites were often surrounded by dump and excavation sites. In fact, industrial activities until the 1970's generated large amounts of wastes which resulted in a relatively large number of dump sites scattered within industrial zones. Technically, each 100 x 100 m pixel of commercial/industrial class was classified as post-industrial if accompanied by at least one pixel of dump site or mineral extraction class, within the 5 x 5 km window. Finally, delineated post-industrial objects were combined with dump sites and mineral extraction sites into 'post-industrial sites' and expressed as percent of the total area of each NUTSx cell for the EU-25. NUTSx regions with at least 0.3 % post-industrial sites in the total territory were defined as post-industrial.

Data from EUROSTAT were grouped into environmental, social and economic categories. This process provided complete data sets for about 20 independent indicators at NUTS2/3 level. Biophysical conditions such as length of vegetation period, precipitation, and average temperatures were obtained from the Intergovernmental Panel on Climate Change (IPCC).

Emission data were obtained from the European Pollutant Emission Register (EPER). The database contains facilities responsible for 90 % of the emissions in Europe. The database is divided into contaminant (metals, organic compounds and gaseous compounds) and activity categories (e.g. smelting, refineries, combustions, etc.). The database is limited to EU-15 countries. Emissions generated by all facilities within a region were summed and expressed in tonnes per km^2 as total metal, organic and gaseous emission from a region. Dump-site density was calculated for each land use class based on the CLC 2002 and expressed as area of these sites per land use class area.

Finally, a questionnaire was developed to collect additional expert knowledge on sustainability issues in post-industrial regions. Issues addressed in this questionnaire were based on existing reports and EEA data, e.g. from the Clarinet and Caracas studies. A web based tool was prepared to conduct the survey among representatives of local and regional administrations, the research community, NGOs and industry. The interactive ARC IMS server gave and will give detailed survey results on post-industrial sites at the regional and the local level.

Cluster analysis was performed to recognize relatively homogenous groups of regions with similar environmental, socio-economic, agricultural and geographical profiles within the EU-25. Cluster analysis was performed by K-means for NUTS-2/3 EUROSTAT data for 2001 or 2002 across the EU-25. The variables in the cluster analysis were selected to cover key social, environmental and economic issues and to ensure the distinction between classes of post-industrial zones. Correlation analysis between preliminary sets of input variables was performed to exclude less important variables which were inter-correlated with key indicators. Variables used to distinguish classes were (1) Density of post-industrial sites (% of total area), (2) Length of vegetative period (days), (3) Mean precipitation in vegetative period IV-X (mm), (4) Unemployment rate (%), (5) Gross domestic product (GDP; Euro per inhabitant), (6) Population density (inhabitants per km^2), (7) Economically active population (% total population), (8) Crude birth rate (N per 1000 inhabitants), (9) Crude death rate (N per 1000 inhabitants) and (10) Employment in industry (% economically active population).

Land use change analysis was based on the CLC layer of changes obtained from EEA – this was the 2005 version of revised data characterizing land use conversions between 1990 and 2000. The CLC database provides information on land use types grouped into artificial areas, agricultural areas, forests and semi-natural areas, wetlands and water bodies. This is the first level of classification; it is further sub-divided into two sub-levels. One-way land use transitions and net transitions between classes were considered, and trend analysis was performed to assess changes in population density, GDP, natural population growth and employment structure within these homogenous areas throughout Europe. The timeframe for this analysis was dependent on available statistics in EUROSTAT database.

The analysis of relationships was performed using Statistica 6.0 software. Pearson's correlation coefficients were calculated to evaluate the significance of linear relationships between land use changes and biophysical and socio-economic variables. Stepwise regression models were generated to find indicators which explain trends in land use transition between various land cover classes. Identification of sensitive regions was based on comparison of key socio-economic and environmental indicators between types, and in relation to the EU-25 average.

Mountains

There are several recognised definitions of mountain areas that have been systematically applied. We have adopted the definition according to Nordregio (2004) in which mountains are identified by a combination of altitude above sea level and roughness of the terrain (Table 1).

Table 1. Identification of European mountains using the criteria ‘altitude’ and ‘slope’ according to Nordregio (2004)

Class [elevation in m]	Additional criteria
> 2500	---
1500 -2499	> 2° slope within 3 km radius
1000 - 1499	> 5° slope within 3 km radius and/or local elevation range > 300 m within 7 km radius
300 - 1499	local elevation range > 300 m within 7 km radius
0 - 299	standard deviation > 50 m for cardinal points

The sensitivity of mountain areas is classified according to UNEP criteria and priority areas for Structural Fund Objectives (Council Regulation, 1999). It is a classification by cross-referencing natural factors with socio-economic indicators (Table 2). The council regulation aims to reduce disparities in development and promote economic and social cohesion in the EU. The effectiveness of the Community's structural assistance is improved by concentrating the assistance, and simplifying its allocation by reducing the number of priority objectives.

Structural interventions of the Commission comprise expenditures for objectives 1 to 3. The 3 priorities of the Structural Funds are:

(Objective 1) Promoting the development and structural adjustment of the regions whose development is lagging behind. All these regions have a number of economic signals or indicators ‘in red’. They indicate low level of investment, a higher than average unemployment rate, lack of services for businesses and individuals, poor basic infrastructure.

(Objective 2) Revitalizing regions with structural difficulties, whether industrial, rural, urban or fishery-dependent. Such areas are faced with socio-economic difficulties that are often the cause of high unemployment though situated in regions whose development level is close to the Community average. These include: the evolution of industrial or service sectors; a decline in traditional activities in rural areas; a crisis situation in urban areas; difficulties affecting fisheries activity.

(Objective 3) Supporting the adaptation and modernization of policies and systems of education, training and employment.

Table 2. Type-classification of mountains as defined by UNEP criteria for mountain areas and priority areas for Structural Fund Objectives[1]

	Objective 1	Objective 2	Not eligible
Areas where altitude creates very difficult climatic conditions (minimum altitude between 600 and 800 m)	High mountain ranges in Spain, in southern Italy (including Sicily) and in Greece (including Crete), Bulgaria, Montenegro, Romania and Norway	High mountain ranges in the Alps (Austria, Switzerland, France and Italy), Andorra, Spain and southern Italy	Certain areas in the Alps of Austria, Switzerland and Italy
Areas at a lower altitude and/or with a steep average slope (usually more than 20%)	Other mountain areas in Spain, Portugal, Corsica, southern Italy (including Sicily), Greece, Bosnia-Herzegovina, Serbia, Macedonia, Romania, Poland, Czech Republic, Slovenia, Hungary and Norway	Other mountain areas in Austria, Switzerland, Germany, France, Italy, Spain and Norway	Certain areas in Austria, Germany, Switzerland, Lichtenstein and Italy
Other areas north of the 62nd parallel and certain adjacent areas	Mountain areas in northern Norway		

[1] Priority areas for Structural Fund Objectives (Council Regulation, 1999)

Coasts

The analysis was started based on NUTSx regions having a shoreline. In addition, those NUTSx regions, located not more than 10 km from the shoreline and having access to the sea via a river (Antwerpen, Oost-Vlaanderen, Comunidad Foral de Navarra) were included.

Data and indicator values were taken for NUTS2 level from EUROSTAT and for NUTS3 level from national statistics. In addition, maps of CLC 1990 and CLC 2000 were used since changes in CLC may indicate endangered regions that may partly be sensitive. CLC biotope layers were also analysed. Information on environmental sensitivity of coastal zones of the 2 European R&D projects LACOAST and EUROSION in the 10 km strip along almost the whole coast of EU was also used. The data available at the EEA site (http://www.eea.eu.int/main_html) forms the background for analysis of changes after 1990. Human Development Indicators were used from the UNDP (http://hdr.undp.org/statistics/data/).

The sensitivity analysis of coastal areas was done by combining indicators. Data available for NUTSx cells was used preferentially. When NUTS3 data were not available, NUTS2 data were considered. The indicator values were calculated for all NUTSx cells having a coastal border. Maps were produced employing ArcGIS 9.1 using the ETRS89 - Lambert Azimuthal Equal Area projection.

Conflicts between the major factors of nature conservation, development, restoration, traditional economic use and natural hazards were considered in the analysis.

Similarly to the post-industrial zones, clustering using the k-means algorithm and Statistica 7 was done to classify environmental, social and economic issues and their combinations. To determine clusters of similar NUTSx areas two procedures of cluster analysis were employed using indicators characterising different aspects of sustainability. Cluster analysis was done with 187 NUTSx cells. Monaco were not included since data were not available.

Islands

The basis of this calculation is the EuroGeographic NUTS0 layer, which excludes certain smaller islands. In addition, the map does not include any ‘overseas countries and territories’ belonging to EU-27 + 3 nor the French Overseas Departments. Since the Norwegian archipelago of Svalbard had not been included in the NUTS0 map it was added to the list of EU-27 + 3 islands.

Due to the lack of existing studies the methodological approach utilised to identify key sustainability issues across European islands was to select a representative sample of study islands and carry out expert interviews identifying key issues for each study island. A set of 28 representative islands and archipelagos was selected for detailed investigation, based on the 1994 ‘Portrait of the Islands’ study (CEC 1994), which however only covered EU-12. The states of Malta and Cyprus were included since these small island states experience island sustainability issues to an even higher degree than other islands due to lack of support, particularly economic support, from a 'mainland'. The set of 28 study islands was drawn up on the basis of the following criteria: (1) For each of the EU-25 countries that have islands, at least one major island or island group was included; (2) The major (in terms of population and size, and political importance such as a high degree of political autonomy) European islands or island groups were included (e.g. Sicily and the Aegean Islands); (3) A selection of both large islands and archipelagos was included (e.g. the Balearic and the Aegean Islands as well as larger islands such as Sardinia and Crete); (4) Islands from both northern and southern Europe were included, as well as those in the Atlantic, in order to ensure a balanced geographical distribution of islands. (5) Islands that are close to the mainland (such as the Tuscan archipelago), as well as ones far from the mainland (such as the Shetland Islands and Pantelleria).

Experts in the study islands were identified through the literature and specialised networks such as the United Nations partnership SUSTIS, the (European) Islands Commission, the Global Islands Network, and the Eurisles project. The questions concerned sustainability issues and indicators, the influence of existing or planned EU polices, and how the EU might best (and least) help the islands under discussion to promote sustainability. A total of 26 experts were interviewed, some representing more than one island.

A list of 143 indicators based on the standard SENSOR list of indicators and on the expert interviews was made. The list was reduced to a final one of 16 indicators, on the basis of four criteria: (1) Is the indicator one of those adopted for SENSOR's overview (Frederiksen and Kristensen, 2008)? (2) How closely does this indicator describe the island's sustainability issue(s)? (3) Are data available for this indicator? (4) Has this indicator an accepted EEA, IRENA or other internationally recognized methodology. The next step was to quantify the indicators. However, considerable difficulties were encountered here as comparable statistics across the islands (Planistat, 2002 and Eurisles, 2002) were not available. The decision was then taken to use comparable data even if the coverage of the data was smaller. A spatial dataset based on these sustainability indicators was developed and used to organize the set of islands into distinct geographical classes. Cluster analysis was performed by K-means and correlation analysis between input variables was performed to exclude those less important variables that were intercorrelated with key indicators.

3 Results and Discussion

Post-industrial zones

The density of post-industrial areas was below 0.3 % of their surface area in 306 NUTSx cells which corresponded to 65 % of the EU-25 NUTSx cells, and 167 NUTSx cells showing a density of post-industrial areas above 0.3 % were classified as post-industrial regions. These cells cover 25 % of the territory and 50 % of the population of EU-25. The threshold value of 0.3 % is consistent with the value of 0.2 to 0.4 % used in studies for brownfields in western countries (Grimski & Ferber, 2001).

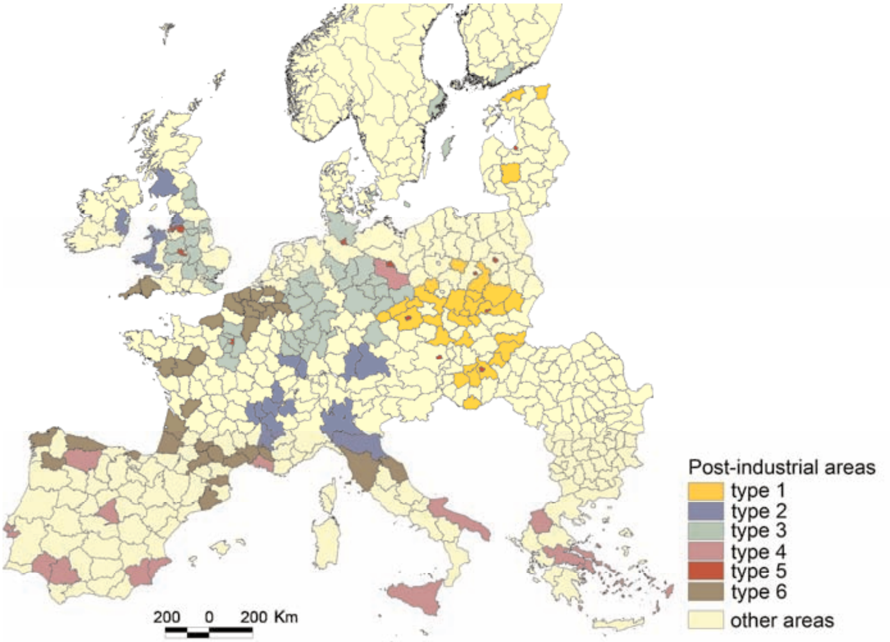


Fig.1. Types of post-industrial zones at NUTSx level across EU-25

The 167 post-industrial NUTSx cells were separated into the following 6 types (Figure 1) based on consistent EUROSTAT data: (Type 1) Eastern transitional industrial, socially and economically weak, (Type 2) Western, economically and socially strong (medium density of post-industrial sites), (Type 3) Western, economically and socially strong (high density of post-industrial sites), (Type 4) Southern, socially and economically weak, (Type 5) Urban, and (Type 6) Western socially weak. Based on the comparison of indicators, Type 1 and Type 4 are most sensitive. The EU countries Bulgaria and Romania were not included in the post-industrial type classification as they were candidate countries before 2007. However, all post-industrial regions of these two countries were sensitive as their GDP was half the GDP of Eastern EU post-industrial units.

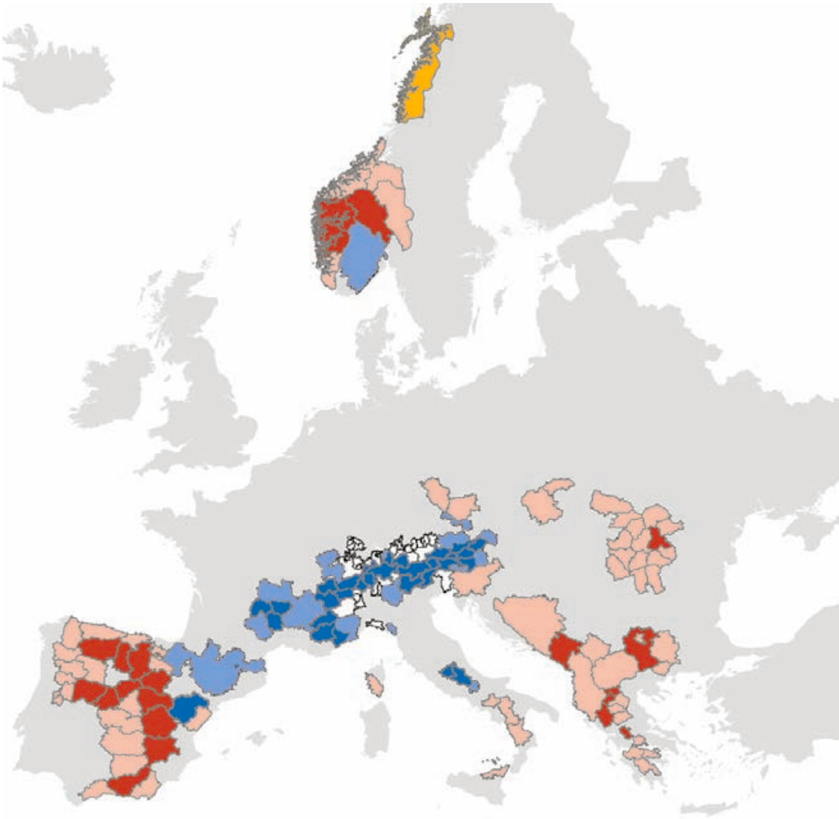
More in detail, Type 1 covers 4.5% of total EU-25 area comprising 31 NUTSx cells, mostly Czech, Hungarian, and Polish regions and single regions from Slovakia, Lithuania and Estonia. These regions are characterised by high unemployment rates, decreasing population and lowest population densities. The mean Gross Domestic Product (GDP) is dramatically lower than for other types and about 25 % of the overall EU-25 average. The relative GDP growth is relatively high with 9.5 % but the real difference to other groups is increasing.

Type 4 is characterised by a high unemployment rate and a low share of economically active population., and covers 4.2 % of the total EU-25 area. It is comprised of 15 NUTSx cells located in the southern part of Europe, mostly Spanish and Greek regions and single regions in Italy, France, Portugal and Germany. There is a marked difference between unemployment rates of males and females: 10.5 % and 21.7 % respectively. The unemployment rate of young people is 32.6 %.

Ten variables were selected as indicators [with respective impact issues according to COM 2005 in brackets] of sensitivity of post-industrial regions from available EUROSTAT indicators: GDP [ECON7, ECON11], Unemployment rate [SOC1], Unemployment under 25 [SOC1], Female unemployment [SOC3], Population density decline [SOC+], Negative natural population growth [SOC+], Low share of active population [SOC1], Gaseous emissions [ENV1], Metal emissions [ENV11], Organic compounds emissions [ENV11], Dump sites density [ENV8] and landscape biodiversity [ENV6].

Mountains

Mountains occur in almost all countries in Europe. They cover 1,900 thousand km^2 and 40.6 % of the total land area with 94.3 million people corresponding to 19.1 % of the total population (EEA, 1999). The mountain distribution varies significantly throughout Europe. They can be isolated, but often stretch to huge mountain massifs over hundreds of kilometres. Mountains are ecologically sensitive, and support important and often rare plant communities. Key issues are (1) tourism and recreation, (2) water reservoir, (3) out-migration and population ageing, (4) natural hazards, (5) transport, (6) global change, (7) natural and cultural heritage and (8) soil degradation.



	Objective 1	Objective 2	Not eligible
higher altitude			
lower altitude			
north of the 62nd parallel			

Fig. 2. Sensitive mountain NUTSx cells according to UNEP criteria and priority areas for Structural Fund Objectives by the European Commission

Around 50 NUTSx cells, home of 22 % of the population, are covered by ‘objective 1’ regions in the period 2000 to 2006 with high mountain ranges in Spain, in southern Italy (including Sicily) and in Greece (including Crete), Bulgaria, Montenegro, Romania and Norway or other mountain areas in Spain, Portugal, Corsica, southern Italy (including Sicily), Greece, Bosnia-Herzegovina, Serbia, Macedonia, Romania, Poland, Czech Republic, Slovenia, Hungary and Norway and finally mountain areas in northern Norway (Figure 2). Characteristics for objective 1 regions are low level of investment, a higher than average unemployment rate, lack of services for businesses and individuals and a poor basic infrastructure. The structural funds aim to support economic activities in these regions by providing the basic infrastructure, whilst adapting and raising the level of trained human resources and encouraging investments in businesses. For objective 1 mountain regions, there are important economic sustainability issues.

Objective 2 regions are all areas facing structural difficulties, whether industrial, rural, urban or dependent on fisheries, although the level of development in these regions is close to the Community average. These areas face different socio-economic constraints that are often the source of high unemployment. For objective 2 regions, social and ecological issues may also arise. Therefore, the High Tatras Mountains were chosen as an objective 1 sensitive area case study in comparison with objective 2 ones of Valais and Eisenwurzen.

Coasts

The geographical identification of coastal NUTSx regions led to 187 cells. The clustering trials on the basis of k-means and NUTSx cells showed high variability between 3 clustering trails. In contrast, the clustering on NUTS2 level separated 6 classes using the following indicators: Population density [n per km²], Unemployment 2004 [%], δ GDP '95 to '02 [%], Relative GDP in 2002 [% of EU-25], GDP per inhabitant '95 to 02 [% of EU-25], GDP per inhabitant, Agriculture in 2003 [%], Forestry in 2003 [%], RAMSAR sites [n per cell], RAMSAR sites [n per km²l], Urban population [%], Ecologically valuable areas [%], R&D in 2004 [mEUR], Coastal length [km], Coastline exposed to erosion [km].

Six coastal clusters were identified (Figure 3): (1) economically and socially strong; the development rate is moderate but GDP is above EU-25 average; high share of urban population combined with low unemployment; high environmental awareness, (2) stable, relatively slowly developing economy with high share of agricultural activities; high share of rural population and relatively low GDP; which causes also a high rate of unemployment; environmental awareness is marginal, (3) moderately developing economy which is slightly influenced by a high unemployment rate, a high share of urban population; GDP remains slightly below EU-25 average, (4) economically and socially very strong; high share of urban population combined with high population density; low unemployment; long coastline; well developed environmental awareness, (5) rapidly growing economy combined with relatively high but decreasing unemployment, low but increasing income; R&D investment rate low; low share of arable land and high share of rural population; in spite of moderate coastal length the highest share of coast exposed to coastal erosion; environmental protection has high variability within the classes (from 14% to 2% of area for

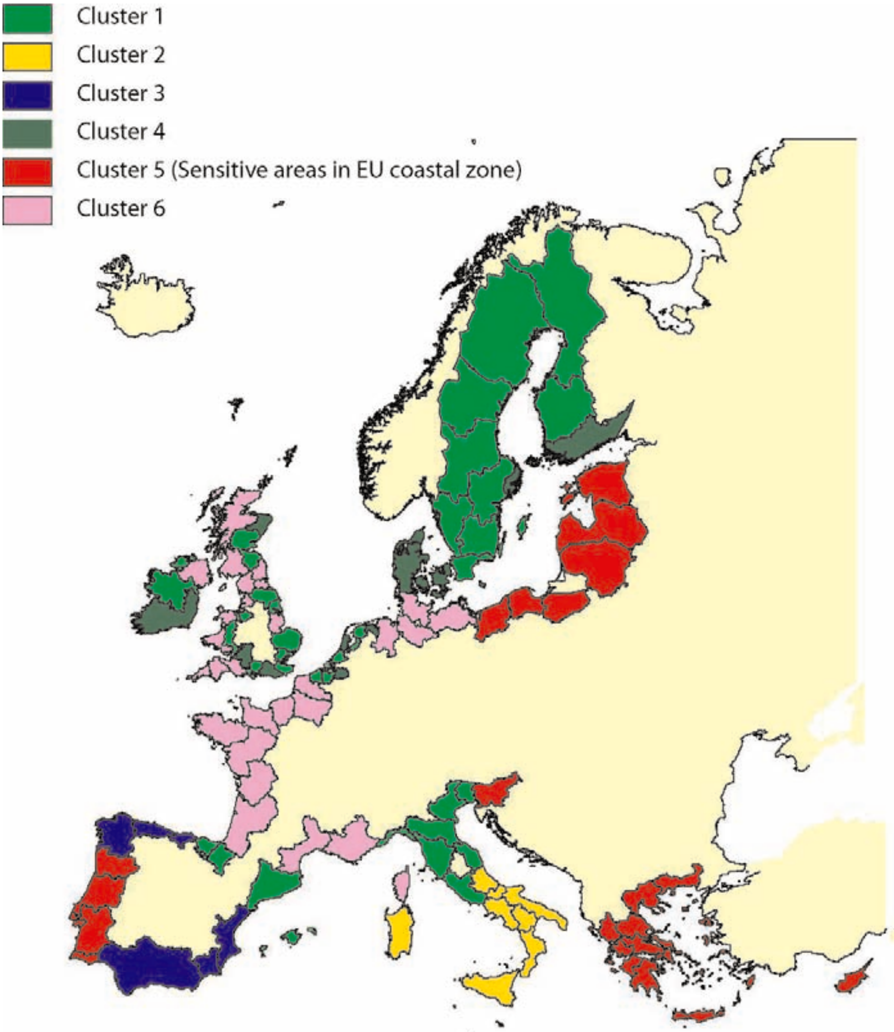


Fig. 3. Classes of European coasts at NUTS2 level

designated areas); however, in the Baltic Sea coastal zone of this cluster environmental and nature protection issues are of high importance and (6) traditionally strong and stable economy with high share of agricultural activities; population density is high and most of population is living in urban areas; in spite of high living standards, high R&D expenditure is needed to avoid economical stagnation.

Class 5 was considered as most sensitive since it showed rapid changes in socio-economic issues and conflicts between intense development for tourism development and nature conservation. Class 5 encompassed 23 NUTS2 cells and included 5 islands.

Islands

A total of 4,966 islands were identified from the EU NUTS-0 map, occupying 265500 km^2 or 5.6 % of the land area of EU-27 + 3. The Norwegian archipelago of Svalbard was added to this list. The Figures including the 150 Svalbard Islands are 5,116 European islands, occupying a land area of 328021 km^2 or 6.8 % of the area of EU27 + 3.

Island regions were found in 136 NUTSx cells, from which 25 NUTSx cells were made up entirely of islands and Corsica and the Canaries consisted of two NUTSx cells. These Islands are: Aland, the Azores, Balearic Islands, Bjornoya, Bornholm, Canary Islands, Channel Islands, Corsica, Crete, Cyprus, Faeroe Islands, Gotland, Iceland, Ionian, Isle of Man, Jan Mayen Islands, Madeira, Malta, North Aegean, Sardinia, Sicily and South Aegean. The rest of the NUTSx units are occupied by islands to varying degrees. For example 63 of these NUTSx regions have less than 1% island territory; another 38 have less than 10% island territory; and 10 regions have between 11 % and 36 % island territory.

The dataset from the 26 expert interviews on the 28 study islands identified the following 12 key sustainable development issues, which reflect the islands 'backwardness' issues identified elsewhere (Planistat, 2002; Eurisles, 2002): (1) High population dynamics, (2) Low potential for economic diversification, (3) Negative impact of land development, (4) High pressure on marine water quality, (5) High consumption of freshwater, (6) Waste management challenges due to small size and remoteness, (7) Tourism pressures, (8) Insularity and peripherality, (9) Declining agriculture and fisheries, (10) Degradation of natural resources and loss of biodiversity, (11) High cost and impact of energy use and (12) Low levels of education and training.

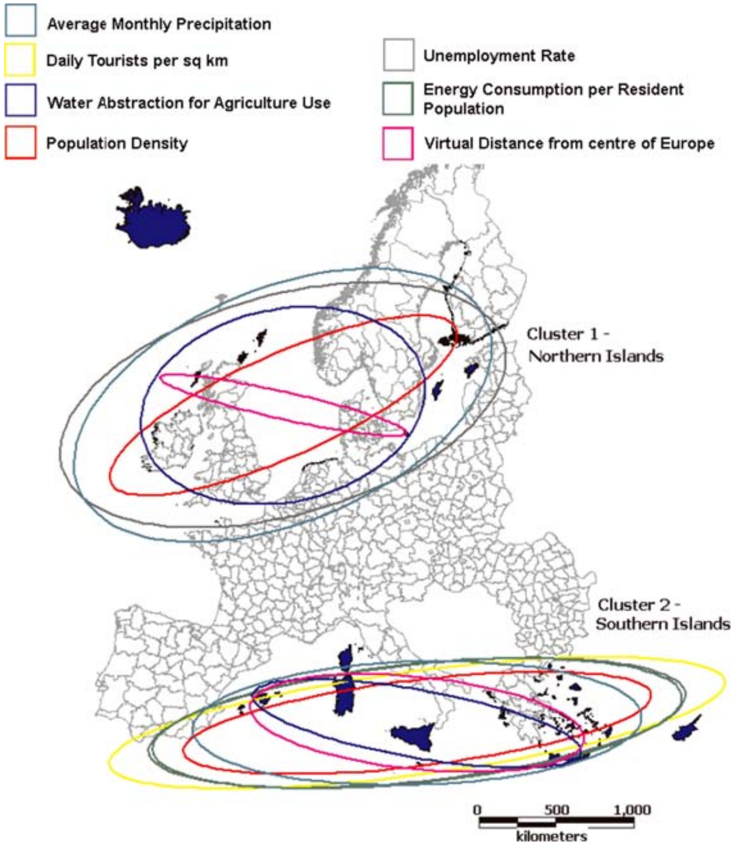


Fig. 4. Classes of islands based on the clustering of sustainability issues of 28 study islands

On the basis of these issues, the following sustainability indicators were identified: (1) Population density, (2) % of population above 65 years, (3) Employment by sector, (4) Unemployment rate, (5) GDP per capita (EURO/National currency), (6) % land built up (proxy: % urban area of total [CLC]), (7) Compliance with Bathing Water Directive, (8) Water abstraction rate (ground and surface) (Proxy: ag. water abstraction rate [IRENA]), (9) Precipitation rate, (10) Municipal waste generation per capita, (11) Daily tourists per square kilometre, (12) Virtual distance from centre of Europe (Eurisles study), (13) % agricultural land use change, (14) % of land covered by Natura 2000 sites (proxy: % land with protective designation), (15) Energy consumption per resident population and (16) % of researchers in relation to active population.

On the basis of a cluster analysis performed spatially on these variables two classes were identified (Figure 4): Northern Islands and Southern Islands. The island Malta, which has a central position in the Southern Islands Cluster, is suggested as sensitive area case study for the European islands. Results show that another impact issue “insularity and vulnerability” should be added to the list of sustainability impact issues elaborated by the EU Commission.

4 Overview of key sustainability issues in sensitive regions in Europe

A first joint overview identified more than 50 % of the NUTSx cells of the EU-25 as sensitive. This was because mountains and coasts were geographically important in more than 100 NUTSx regions each. More specific classes in each of the 4 sensitive region types were identified mainly on the basis of socio-economic data from EUROSTAT. Additional environmental indicators were acquired to be consistent with the three pillars of the sustainability impact assessment. This more specific classification helped us to identify high priority cells with reference to key sustainability issues and UNEP standards. The overview here defined about 31% of the area as sensitive. There is a minimal overlap between 2 or more sensitive area types, not exceeding 2% of total area.

Sensitive regions frequently showed indicator values differing from the EU-25 average. This is illustrated for the 8 chosen indicators relating to sustainability issues and land use (Figure 5). For example, the percentage of agricultural areas was substantially smaller at coasts and in post-industrial zones with 9 % and 24 % respectively, in contrast to 52 % for the EU-25 overall. This indicates the competition between agricultural land use and other land use types and land use functions (Perez-Soba et al., 2008). Coasts showed both many small and many large farms in comparison to the EU-25. For mountains, low population growth is typical. In contrast, population growth was high on islands. For islands, the 8 selected indicators were closer to the EU average. The visualisation in Figure 5 can be used to reflect the conditions in the selective region type and to discuss the case specific threshold and limits (Bertrand et al. 2008; Haynes-Young and Potschin 2008). Figure 5 emphasises values exceeding the EU average by more than 30 % and being outside the grey circle which are non-typical and may thus be discussed as critical. The indicator values inside the grey circle can be considered as non-critical.

The data availability relating to environmental issues was poor at NUTSx level. Furthermore, islands issues may not be representative as available statistics often concern major NUTSx regions of which islands represent a minor part. In addition, extreme indicator dynamics in islands are frequently not well reflected at the NUTSx level.

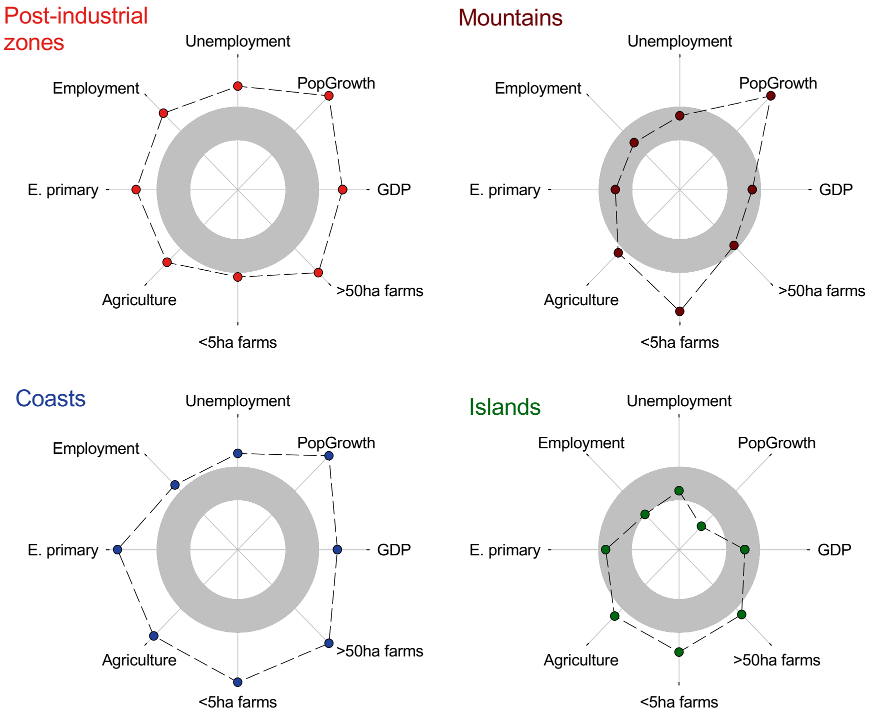


Fig. 5. Eight indicators in the 4 sensitive area types relative to the EU-25 average. The grey circle represents the EU-25 average (100 %) ± 30 %. Dots outside the circle represent the visualisation of a critical status compared to dots on and inside the circle. Abbreviations: PopGrowth - Population growth; > 50 ha farms - percentage of farms larger than 50 ha; < 5ha farms - percentage of farms smaller than 5 ha; ; Agriculture - agricultural area in %; E. primary - Employment in the primary sector

Information from sensitive regions is highly relevant for the development of ‘Sustainability Impact Assessment Tools’ (SIAT; Sieber et al., 2008). The SIAT is designed for ex-ante impact assessment of land-use relevant policies and integrates about 60 indicators designed for scenarios of the policy cases, Bioenergy, Common Agricultural Policy, Biodiversity, Forest, Transportation and Tourism (Kuhlman et al., 2008). Out of this European wide overview 3 out of 7 sensitive area case studies were also chosen as regular test regions, to test the analysis of the NUTS X cluster regions (Figure 6). These 3 regions are Silesia (Poland), the Estonian costal zone and Malta. The other 4 case studies are Lusatia (Germany), Eisenwurzen (Austria), High Tatras (Slovakia) and Valais (Switzerland). From the 7 case studies, information (data) was acquired, harmonised and pre-processed to enable the testing of the SIAT on both, regularly managed areas and sensitively managed areas. Based on this strategy land use impact on average and on more extreme but still typical conditions will become evident. The clear advantage of this approach is that it allows policy makers a relevant judgement on land use practices on a wider range of existing site conditions.

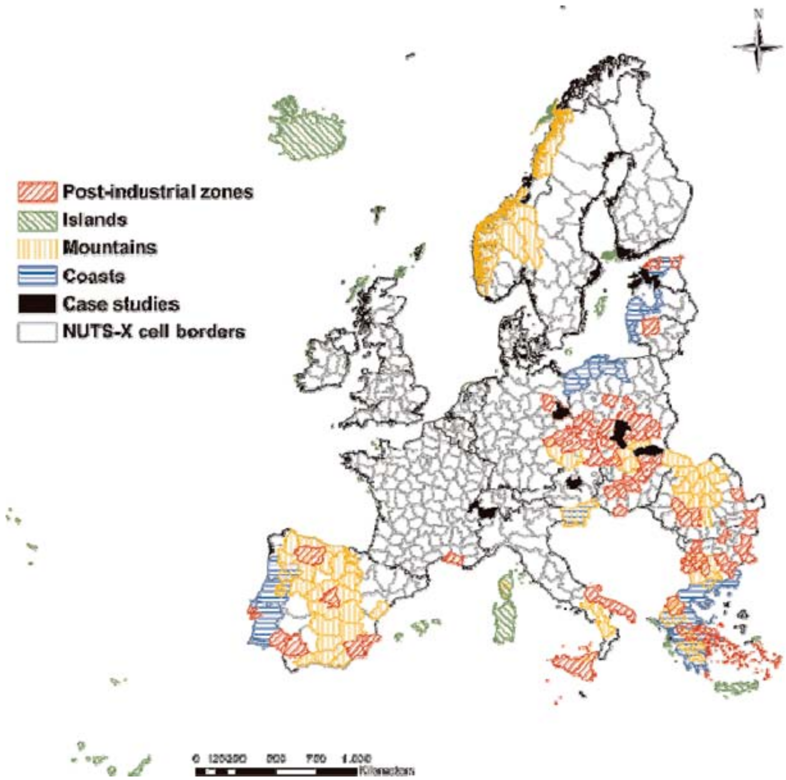


Fig. 6. Geographical location of sensitive regions and sensitive area case studies in Europe

From the social perspective, coasts and post-industrial zones face significantly higher unemployment rates compared to regular or average EU-25 regions (Figure 5). The unemployment rate here particularly marginalizes females reaching 16% of the active population. Negative population growth was associated with high unemployment in post-industrial zones and coasts, where it was substantially lower than in the EU-25. The economic performance measured by GDP per inhabitant was less than 50 % of the EU-25 in coasts and post-industrial zones. All 8 indicator values in 0 exceeded the EU-25 average in the post-industrial zones and coasts.

The geographic overview of sensitive regions in Figure 6 shows that in area terms, mountain sensitive regions were the most important with 14 % of the total EU area, whereas the contribution of post industrial, islands and coastal regions was 8 %, 6.8 % and 6 % respectively.

In contrast to this approach with paying special attention to pre-defined sensitive regions, the clustering of the entire European 581 NUTSx cells in the Spatial Regional Reference Framework (SRRF, Renetzeder et al., 2008) separated approximately 30 clusters by using biophysical, socio-economic and administrative parameters. However, the SRRF clusters may not match to the separated sensitive classes and thus policy measures to be applied in sensitive regions may refer to other regions than to be applied to SRRF classes.

Fig. 7. Cluster 2600 NEMFOR (Renetzeder et al. 2008) includes Nemoral regions in Sweden Estonia, Finland, Latvia. Large parts are lowlands (> 80%) or hills (<20%), parent material is formed by different sediments. The population density is varying between 103 and 165 inhab./km2, GDP index between 66 and 104. A-round 80% of the land is covered by forests

5 Conclusions

1. Based on most consistent EUROSTAT and some complementary data related to sustainability issues and using cluster analysis, UNEP priorities and expert knowledge, sensitive post-industrial zones, mountains, coasts and islands were identified across Europe at NUTSx scale. Various dis-aggregation and aggregation procedures were necessary in this bottom-up approach. Identified key sustainability issues

have been consolidated into one list of sustainability issues for all EU27 + 3 sensitive regions.

2. Sensitive regions were located in the southern, western and eastern EU27 + 3 area and face specific environmental, social and economic problems such as low GDP, low natural population growth, high unemployment rate, small farm sizes and high pressure on valuable biotopes related to global markets and political change.
3. Forty-six post-industrial NUTSx cells of 581 EU-25 + 5 cells were classified as sensitive based on analysis of their socio-economic and environmental profile. Eastern and southern groups of post-industrial regions were defined as sensitive. Sensitivity is mainly driven by high unemployment, low GDP and demographic indicators such as population decline or low share of active population.
4. The sensitive mountains were identified according the objective 1 of the UNEP approach. About 50 NUTSx cells were referred to as sensitive across Europe.
5. At NUTS2 level, 28 sensitive coastal cells were identified. An analysis was not feasible at NUTSx scale. Main conflicts in these cells are caused by rapidly growing economy combined with relatively high but decreasing unemployment, low but increasing income, a low rate of R&D investment, and high ecological value of ecosystems under pressure.
6. Island regions were found in 136 NUTSx units, and 24 of these are entirely made up of islands. There was a lack of statistical data on sustainability issues for European islands mainly due to the fact that they are often classified at lower than NUTS2 level..
7. In total, about 31% of the EU27 + 3 area was defined with as sensitive our methodology. There is a minimal overlap between 2 or more sensitive area types, not exceeding 2% of total area.
8. The delineation was based mainly on social and economic issues since the regional data bases on environmental indicators are limited and did not allow the separation of classes of sensitive regions.
9. The study showed unique patterns of socio-economic and environmental characteristics in the sensitive region types, which differed from regular European regions. Thus land use will change differently in response to EU policies. SIAT should be tested within sensitive regions to assess its robustness in sensitive regions which cover a substantial portion of the European territory.

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Abbreviations

AHP	Analytic Hierarchy Process
AIDS	Almost Ideal Demand System
ATEAM	Advanced Ecosystem Analysis and Modelling
B&B	Tourism demand model
BAP	Biomass Action Plan
CAFÉ	Clean Air for Europe
CAP	Common Agricultural Policy
CAPRI	Common Agricultural Policy Regional Impact Analysis
CBA	Cost Benefit Analysis
CBD	Convention on Biological Diversity
CEA	Cost Effectiveness Analysis
CEC	Commission of the European Communities
CGE	Computable General Equilibrium
CGIAR	Consultative Group on International Agricultural Research
CLC	CORINE Land Cover
CLUE	Conversion of Land Use and its Effects Model
CQC	Countryside Quality Counts
DG	Directorate Generale
DPSIR	Driving force, Pressure, State, Impact, Response
EAAC	European Environment and Sustainable Development Advisory Councils
EC	European Commission
ECSG	Executive Committee Study Group
EEA	European Environment Agency
EEAC	European Environmental Advisory Councils
EFISCEN	European Forest Information Scenario Model
EIA	Environmental Impact Assessment
EPER	European Pollutant Emission Register
ESPON	European Spatial Planning Observation Network
ETRS	European Terrestrial Reference System
EU	European Union
EUROSTAT	Statistical Office of the European Communities
EURURALIS	Land use scenario study
FAO	Food and Agricultural Organisation
FUA	Functional Urban Area
GDP	Gross Domestic Product
GIS	Geographical Information System
GTAP	Global Trade Analysis Project model

GUI	Graphical User Interface
HDI	Human Development Index
IA	Impact Assessment
IGBP	International Geosphere-Biosphere-Programme
IHDP	International Human Development Programme on Global Environmental Change
IIASA	International Institute for Applied Systems Analysis
INSPIRE	Infrastructure for Spatial Information in Europe
IPA	Impact Pathway Approach
IPCC	Intergovernmental Panel on Climate Change
IRENA	Indicator Reporting on the Integration of Environmental Concerns into Agricultural Policy
ISA	Integrated Sustainability Assessment
ISG	Inter-Service Steering Group
JRC	Joint Research Centre
LFA	Less Favoured Areas Compensation Scheme
LUCC	Land Use and Land Cover Change Project
LUF	Land Use Function
MAUT	Multi-Attribute Utility Theory
MCA	Multi-Criteria Analysis
MCPFE	Ministerial Conference on the Protection of Forests in Europe
MDG	Millennium Development Goals
MEA	Millennium Ecosystem Assessment
MFA	Multifunctional Agriculture
MS	Member State
NEMESIS	New Econometric Model for Environment and Strategies Implementation for Sustainable Development
NEPA	National Environmental Protection Act
NGO	Non-Governmental Organisation
NSDS	National Sustainable Development Strategy
NUTS	Nomenclature of Territorial Units for Statistics
OECD	Organisation for Economic Co-operation and Development
OpenMI	Open Modelling Interface
PCA	Principal Component Analysis
PE	Partial Equilibrium
PLS	Primary Landscape Structure
PMP	Positive Mathematical Programming
PRELUDE	Prospective Environmental analysis of Land Use Development in Europe
PROMETHEUS	world energy model
PSR	Pressure, State, Response
R&D	Research and Development

RAINS	Regional Air Pollution Information and Simulation
REP	European Regional Economic Profiles
SABE	Seamless Administrative Boundaries in Europe
SACS	Sensitive Area Case Studies
SCS	Sustainability Choice Space
SD	Sustainable Development
SEA	Strategic Environmental Assessment
SEAMLESS	System for Environmental and Agricultural Modelling
SEEA	System of Environmental and Economic Accounting
SENSOR	Sustainability Impact Assessment: tools for environmental, social and economic effects of multifunctional land use in European regions
SIA	Sustainability Impact Assessment
SIAT	Sustainability Impact Assessment Tools
SICK	Urban land use model
SLS	Secondary Landscape Structure
SMCE	Social Multi-Criteria Evaluation
SQL	Structured Query Language
SRRF	Spatial Regional Reference Framework
SSP	Strategic Planning and Programming Cycle
TBL	Triple Bottom Line
TIM	Transport Infrastructure Model
TLS	Tertiary Landscape Structure
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
WCED	World Commission on Environment and Development
WTO	World Trade Organisation
YASSO	Dynamic soil carbon model