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).

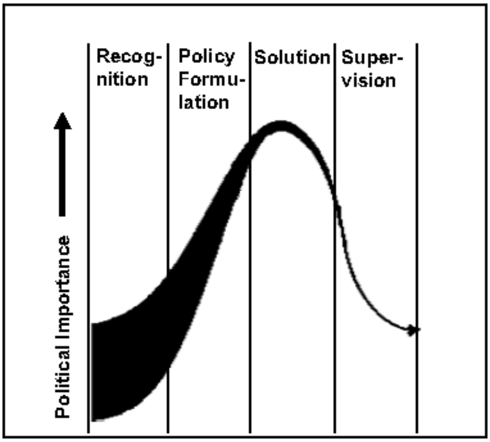

Fig. 1. Policy life cycle (Winsemius 1986)

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 km^2 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 $g = (g_1, g_2, \ldots, g_i, \ldots, g_n)$, 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 "∘" 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 "≈" 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).

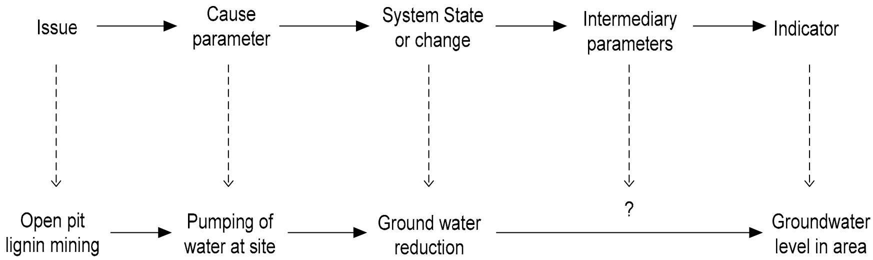

Fig. 2. Ground water-causal chain translated into an indicator

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.

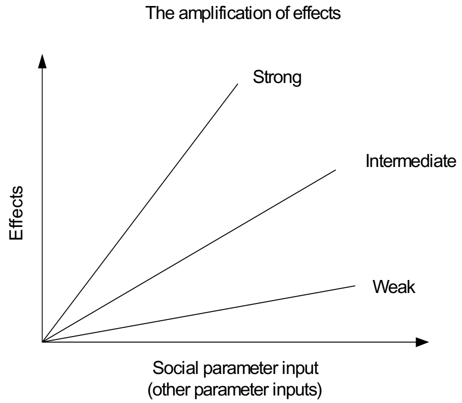

Fig. 3. Three-part input choice of effects on response functions (Haraldsson 2007)

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).

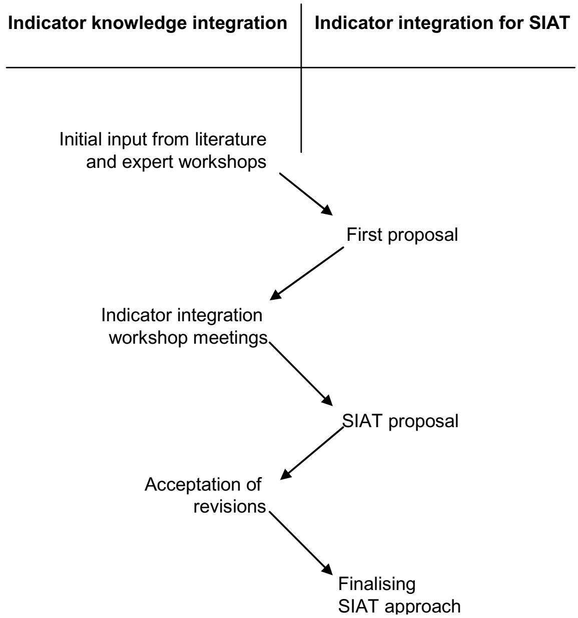

Fig. 4: Methodology for the workflow of indicator integration into causal chains.

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).

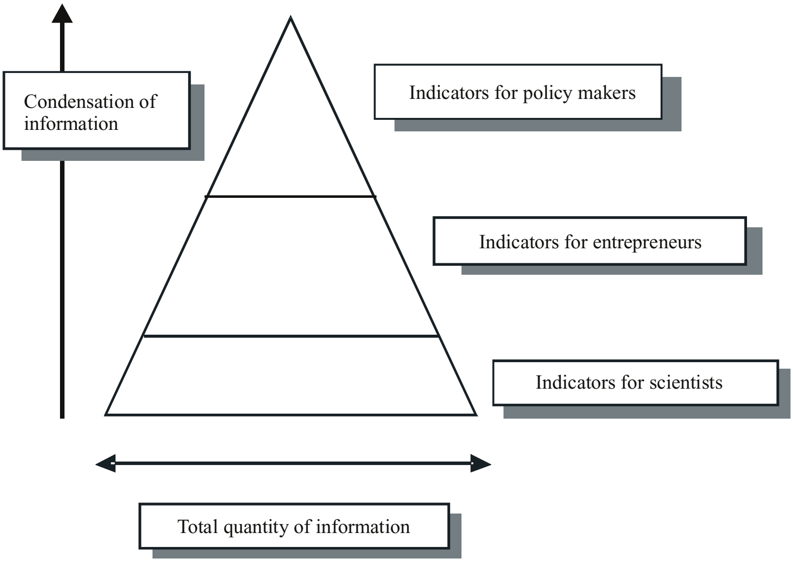

Fig.5. Relationships between indicators (Braat 1991)

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).

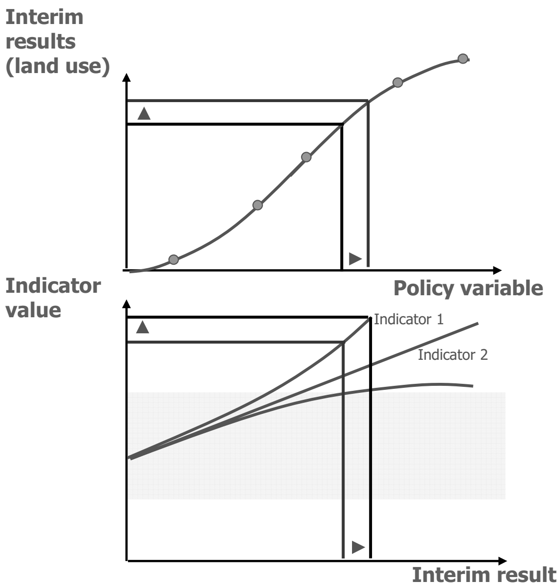

Fig. 6. Dual approach of policy and indicator functions in SIAT

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.

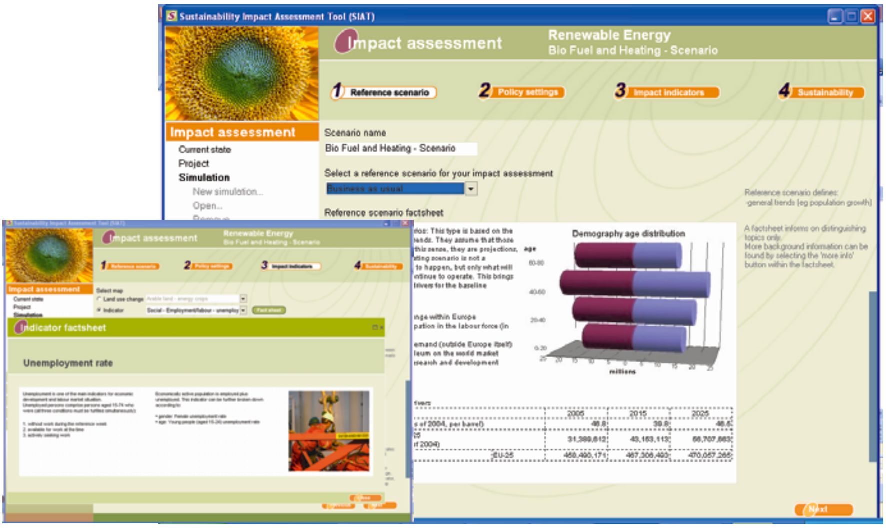

Fig. 7. Two exemplary fact sheet categories (a) embedded (large screen shot) and (b) new frame

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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