Land use functions – a multifunctionality approach to assess the impact of land use changes on land use sustainability

Marta Pérez-Soba[1], Sandrine Petit[2], Laurence Jones[3], Nathalie Bertrand[4], Vincent Briquel[4], Luigi Omodei-Zorini[5], Caterina Contini[5], Katharina Helming[6], John H. Farrington[7], Maria Tinacci Mossello[5], Dirk Wascher[1], Felix Kienast[8], Rudolf de Groot[9]

(1) Alterra WUR, Wageningen, The Netherlands
(2) INRA-ENESAD-Université de Bourgogne, France
(3) Center for Ecology and Hydrology (CEH), United Kingdom
(4) Cemagref, Research Unit Development of Mountain Territories, Grenoble, France
(5) University of Florence, Italy
(6) Leibniz-Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany
(7) University of Aberdeen, United Kingdom
(8) Swiss Federal Institute for Forest, Snow and landscape Research WSL, Birmensdorf, Switzerland
(9) Environmental Systems Analysis Group, Wageningen UR, Wageningen, The Netherlands

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.

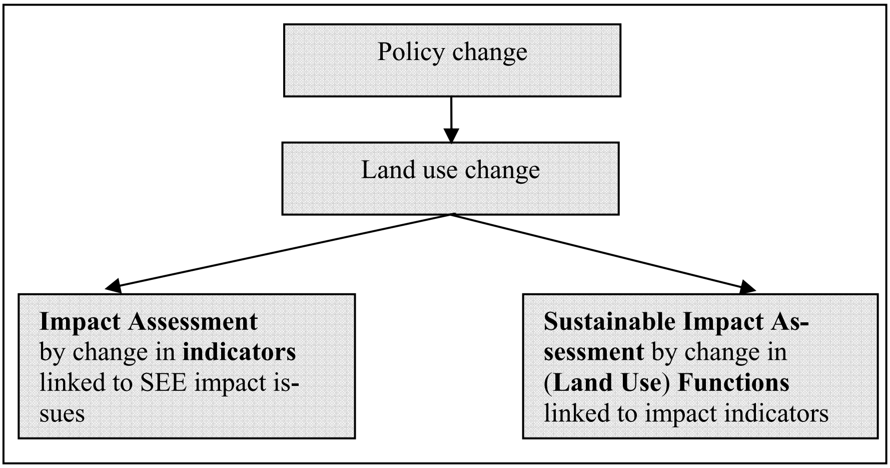


Fig. 1. The role of the LUFs concept in the evolution from Impact Assessment, based on indicators linked to societal, economic and environmental impact issues, to Sustainable Impact Assessment based on Land Use Functions

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 Impac	t 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 Impac	t 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 Impac	t 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 Impac	t 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 Impac	t 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 Impac	t 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 Impac	t 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

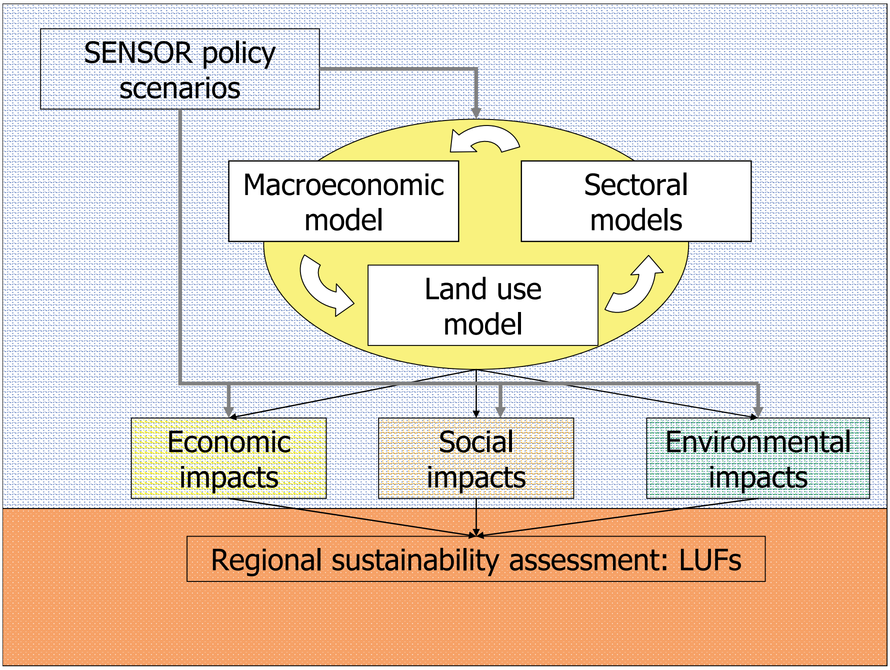


Fig. 2. The general framework for regional impact assessment in SENSOR

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.

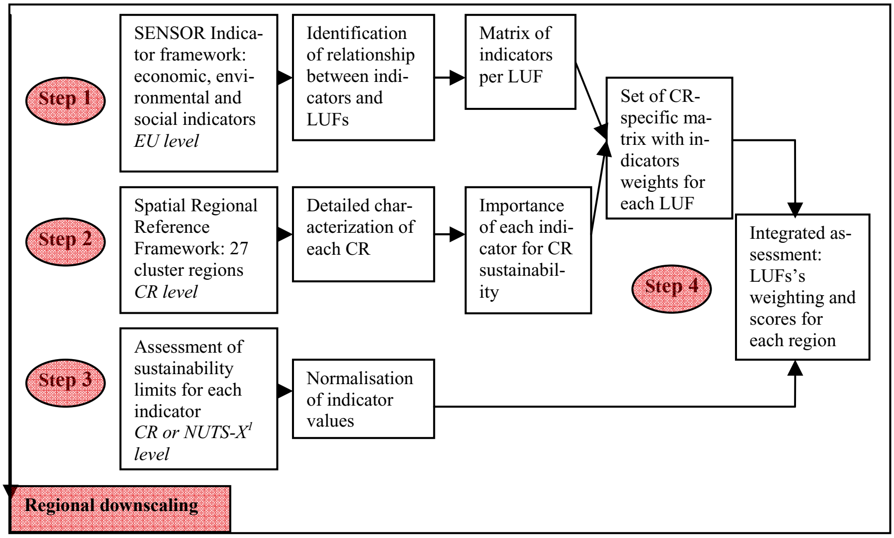


Fig. 3. Methodological approach for integrated Sustainability Impact Assessment at regional level based on the LUFs concept

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.

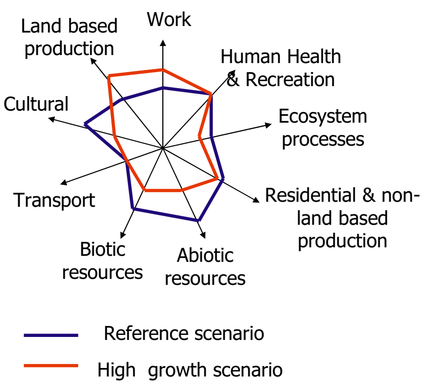
Step 4. Integrated assessment of the effect of a policy scenario on the sustainability of the land use in a region

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.

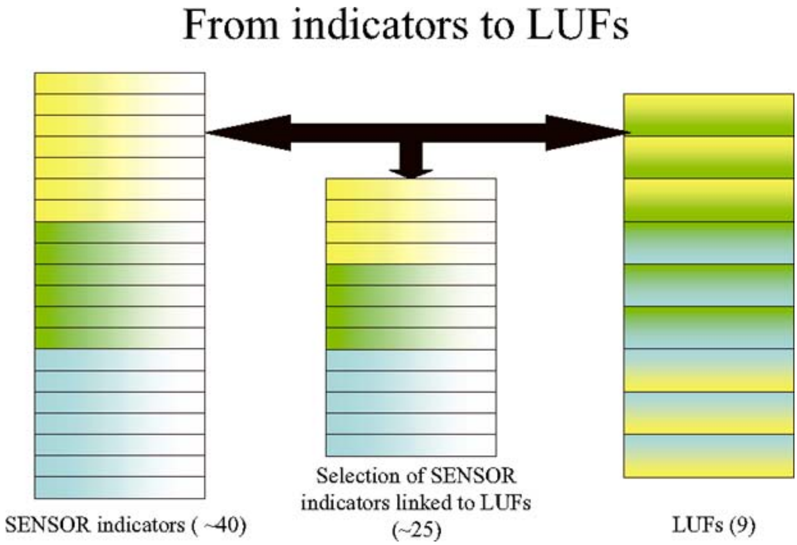


Fig. 4. The LUF concept simplifies the classic complex Impact Assessment based on a large number of indicators, by grouping the indicators into nine land use functions.

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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