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System for Environmental and Agricultural Modelling;
Linking European Science and Society

Sustainable Development Indicator Frameworks and Initiatives

G. Geniaux, S. Bellon, C. Deverre, B. Powell

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SEAMLESS integrated project aims at developing an integrated framework that allows ex-ante assessment of agricultural and environmental policies and technological innovations. The framework will have multi-scale capabilities ranging from field and farm to the EU25 and globe; it will be generic, modular and open and using state-of-the art software. The project is carried out by a consortium of 30 partners, led by Wageningen University (NL).

Email: SEAMLESS.office@wur.nl
Internet: www.SEAMLESS-ip.org

Authors of this report and contact details:

Name: Ghislain Geniaux — Partner acronym: INRA
Address: INRA Ecodéveloppement
Site Agroparc, Domaine St Paul
84914 Avignon Cedex 9
FRANCE
E-mail: geniaux@avignon.inra.fr

Name: Blaise Powell — Partner acronym: INRA
Address: INRA Ecodéveloppement
Site Agroparc, Domaine St Paul
84914 Avignon Cedex 9
FRANCE
E-mail: bpowell@avignon.inra.fr

Name: Stéphane Bellon — Partner acronym: INRA
Address: INRA Ecodéveloppement
Site Agroparc, Domaine St Paul
84914 Avignon Cedex 9
FRANCE
E-mail: bellon@avignon.inra.fr

Name: Christian Deverre — Partner acronym: INRA
Address: INRA Ecodéveloppement
Site Agroparc, Domaine St Paul
84914 Avignon Cedex 9
FRANCE
E-mail: deverre@avignon.inra.fr

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Executive summary

SEAMLESS aims at designing a tool enabling to assess and compare policy options of the Common Agricultural Policy (CAP), in a Sustainable Development perspective. This encompasses agricultural and environmental policies and technological innovations. Within the project, WP2 is in charge of elaborating indicators for this purpose. Which indicators are chosen, and how they are organized, determines the scope of SEAMLESS and its definition of the agricultural system, contributing to SD in Europe.

In this paper we rely on a critical literature review to analyse what the organisation of indicators for sustainable development into a framework can bring to WP2 objectives. First the framework translates the vision of SD carried by the promoter of the assessment, what is studied, how and for what purpose. So principles and issues used in the SD paradigm are presented. Then, the framework organizes indicators into a meaningful presentation. Different frameworks allow to take into account the balance between dimensions of SD, between issues, between pressure or response indicators… Different frameworks integrate a variable number of desired properties for indicators, thus ensuring such properties are accounted for. The properties which are not integrated in the framework are generally mentioned in indicative criteria lists, leaving their consideration to the individual indicator choice.

We then present available major sustainable development indicator frameworks (SDIF). Their advantages and limits are discussed, distinguishing indicator lists, aggregated and composite indicators. We notably point how certain frameworks are explicitly or implicitly adapted to account for : 1) certain interfaces such as economy/environment or society/environment,… 2) weak or strong sustainability, 3) inter or intra-generational equity, 4) comparability in space and time or adaptability to local context and participative methods, 5) dependence relations involving the studied system. Approaches dealing more precisely with agro-ecosystems are then presented. From the literature reviewed here, we have notably retained that the systemic approach permits a complete and balanced SDIF.

But SEAMLESS presents a number of challenges that are not dealt with, or solved in a satisfactory manner in the literature reviewed. The first challenge is dealing with different scales, and with the agricultural sector. The nature of the agricultural system and of its relation to the rest of society is specific at some scales. This could condition the link between scales, which still has to be modelled. Another point is dealing separately with different agricultural sub-sectors or policies related to CAP. This involves making SD related *ex post* assessments as well as *ex ante* comparison between competing policy options.

The methodological aspects of elaborating composite indicators are also reviewed. How they could be adapted to these challenges is discussed in the final chapter, where methodological choices are made to propose an SDI framework for SEAMLESS. The proposed framework is characterised by:

- at each scale (farm, community, region, nation, Europe), an adapted systemic framework allowing to flexibly choose indicators representing systemic properties, according to local context and specific purpose;
- the articulation of two systems: the agricultural system encompassing the agricultural land, the people working or living on this land and their families, in relation with the total system in a sustainable development perspective. At each scale (level) specific relations between society and the agricultural system are thus emphasized. The farm scale is not territorially defined and the agricultural system merges with the total system, so the more general sustainable development perspective at this level will depend on the link with territorial scales. Possible Data accessibility problems at community level may lead us to integrate rural aspects inherent to this scale into the regional scale;
- differentiating *ex post* and *ex ante* analysis, for various policies;
- enabling to asses these policies separately and completely, because all indicators derived within the framework can be relative to the particular policy of interest;
- an aggregation scheme for a candidate list of sub-indicators, along with a complementary list of indicators and contextual variables to be used for post-model analysis;
- The necessity for SEAMLESS to formalise correspondances between properties relative to the systemic logic, and the indicators chosen to represent them - which can be originally identified through different logics (issues for example).

Thorough *ex ante* policy analysis in the proposed framework requires that the user be provided candidate indicators adapted to concerned policies. It is thus expected from WP1 and WP7, to provide a manageable list of policy fields and policy options useful to final users, in order to engage in elaborating appropriate lists of indicators within WP2.

1 Introduction

This paper presents and assesses the panorama of main Sustainable Development Indicators (SDI) frameworks that exist in the literature. Its objective is to facilitate the selection and development of a framework adapted to WP2 in SEAMLESS. It underlines the great diversity of available frameworks, within national and international initiatives. Indeed, previous PDs produced within SEAMLESS give little account of such a diversity and possible methodological choices, particularly concerning the range of different principles and criteria for organising these frameworks.

The second chapter of the document proposes a detailed review of stabilised and emergent principles stemming from the idea of sustainability, as it gradually crystallized on the political and scientific scene. A brief chronological presentation of this emergence and stabilisation is given. It aims to illustrate the continuous enlargement of principles underlying SD and the accompanying conditions for its implementation, being the main cause of the continuous evolution and revision of developed frameworks. This part ends by a simple reminder of principles our future framework will have to stand up to.

The third chapter aims to define what an indicator and a framework is, when developed in the context of sustainable development. We define what we expect from an indicator and propose a simple typology of indicators which is used to discuss the main differences and methodological issues, related to aggregated indicators, composite indicators and lists of indicators. This part is focused on general technical and methodological aspect of the construction of a SDIF.

The fourth chapter discusses in detail eight (8) existing SDI Frameworks. Theoretical and methodological presuppositions of these respective frameworks are analysed, and the SD vision they convey is illustrated. The frameworks are described in four sections by identifying their main organising principles. In a first section, we present frameworks leading to indicator lists. They differ from those used for aggregated or composite indicators, introduced in a second section. In a third section some agricultural and rural specific frameworks are proposed. The fourth section presents and discusses transversal concepts of SDIF that did not lead to a formal and applied SDI framework but contribute to our objective.

The fifth chapter explores the variety of indicators used in the agricultural sector when agriculture is related with environmental and sustainability issues. In the first of the four sections, we present categories of indicators to assess the sustainability of agro-ecosystems including: agricultural, agri-environmental, and ecological indicators that can be used in SEAMLESS. Secondly, we show how the choice of indicators depends on the underlying vision of the environment attached with disciplines or their integration. The third section details initiatives corresponding to the previous categories of indicators identified and ways to represent sets of indicators. The last section includes a brief discussion on temporal and spatial scaling issues.

The sixth and last chapter proposes a framework adapted to the WP2 objectives and constraints. A systemic organization of SDI, adapted from Bossel (1999) is presented. The framework is characterised by:

- at each scale (farm, community, region, nation, Europe), an adapted systemic framework allowing to flexibly choose indicators representing systemic properties, according to local context and specific purpose;

- the articulation of two systems: the agricultural system encompassing the agricultural land, the people working or living on this land and their families, in relation with the total system in a sustainable development perspective. At each scale (level) specific relations between society and the agricultural system are thus emphasized. The farm scale is not territorially defined and the agricultural system merges with the total system, so the more general sustainable development perspective at this level will depend on the link with territorial scales. Possible Data accessibility problems at community level may lead us to integrate rural aspects inherent to this scale into the regional scale;
- differentiating *ex post* and *ex ante* analysis, for various policies;
- enabling to asses these policies separately and completely, because all indicators derived within the framework can be relative to the particular policy of interest;
- an aggregation scheme for a candidate list of sub-indicators, along with a complementary list of indicators and contextual variables to be used for post-model analysis;
- The necessity for SEAMLESS to formalise correspondances between properties relative to the systemic logic, and the indicators chosen to represent them - which can be originally identified through different logics (issues for example).

The material collected for this PD – particularly all the lists of indicators proposed in all the SDI frameworks reviewed - and an analytical grid of criteria for the selection of indicators constructed by us to compare frameworks are presented in Appendix .

2 Sustainability principles

2.1 Brief historical review of basic and complementary principles for sustainability and sustainable development

Available Sustainable Development Indicator Frameworks (SDIF) are built, explicitly or implicitly, on a set of underlying sustainable development principles. These principles have evolved since the emergence and stabilisation of the concept of sustainable development itself in the 1987 Bruntland commission report (*"Our Common Future", WCED, 1987)*. As these principles play a central role for SDIF, it is important to identify these principles and where they come from. Their evolution is tightly connected to the large international initiatives concerning reflection about and promotion of SD.

Previous benchmarks dealing with the notion of **sustainability** can be found in agronomic and agro-ecosystems related disciplines. According to Conway (1983) sustainability is the ability of a system to maintain productivity and is considered as a specific property of agro-ecosystems. This is consistent with the forestry concept of sustainability ("nachhaltigkeit") developed during the XVIIIth century, evolving through the notion of sustainable yield, and also applied to agricultural crops (Plucknett and Smith, 1986). Besides this scientifically based "agro-ecological production" path, Becker (1997) also identifies another emerging "normative" path for the concept of SD. This second path shifts from the notion of "wise use" in the RAMSAR convention to the notion of "sound strategies" for the United Nations Conference on Environment in Stockholm (1972); both terms being even more normatively connoted than sustainable development itself). These two paths come together in an economic definition of the concept of SD at the WCED in 1987. However, the exact term of SD seems to have appeared already in a text from IUCN in 1980 (World conservation Strategy)

The *World Commission on Environment and Development* (WCED) of 1987 is consequently one of the first locations of emergence and crystallization of SD principles. The four following principles are acknowledged:

- Inter-generational equity
- Intra-generational equity
- Environmental protection integral to economic development
- Public participation

The **three first principles** constitute the heart of the notion of SD and have been integrated in the majority of SDIF (UN, 1996). This has not been the case for public participation which only later initiated a methodological reflection on the means to manage it.

Recognition of biodiversity protection as a necessary condition to SD enforcement appeared during the Rio conference in 1992. It is also in this conference that the principle of local knowledge preservation, entered as an important dimension of sustainable development.

In the middle of the nineties, and in the line of the principles affirmed in Rio, a number of **complementary principles** were recognised and were used in different SDI initiatives. Work done for the Rosenthal Workshop (UN, 1996) and continued by Murcott (1997) for the conference on SDI (AAAS annual Conference, Seattle, Washington) enables to identify the rationale of these complementary principles.

The necessity of accounting for concerned population's quality of life, and of having recourse to the notion of environment's carrying capacity, had explicitly been mentioned as founding principles as early as 1980 during the Geneva conference (IUCN, UNEP, WWF, Caring for the Earth: a strategy to sustainable living) and have become unavoidable notions in numerous frameworks. Measuring the satisfaction of basic needs and the Provision of social self-determination and cultural diversity had gained official recognition during IICCD (Ottawa 1986), and were partially re-entered by the Rio principles.

Some principles have for their part found official recognition and a political existence within national SD initiatives and only later were acknowledged by international initiatives. This is the case for Shared Responsibility (among all levels of government and internationally) which is part of Canada's Green Plan of 1990. It is in Australia's 1992 Green Plan that ideas relative to the precautionary principle found a beginning of political recognition at national level within the SD issue (Murcott, 1997). The principle that could be called international perspective and aims at linking domestic sustainability to external sustainability is also affirmed in Australia's Green Plan of 1992 (Murcott, 1997).

More generally, dealing with the fact that sustainability of a dynamic system is related to that of other (possibly embedded) systems, is the heart of system-based approaches to SD. Building on work where the method was applied to specific dimensions such as ecosystems or economy, this approach of SD issues was increasingly recognized within different initiatives, without being met with sufficient willingness to operationalise it.

A principle, which today is widely used as a basic principle of several SDIF, aims at promoting integrated life-cycle management and closed material cycles in the chain of raw materials. Having its roots in the 1970's debates that followed the Club de Rome, it found explicit political definition in Netherlands's 1990 national environmental policy plan.

2.2 Stabilized and thematic pillars

The extension of the notion of progress to the environmental and social spheres is present in the founding principles of sustainable development. We can however notice that the elements to integrate in these spheres become more and more numerous as the principles of SD is developed and refined. The same can be said about the links between these spheres. Nonetheless, although the systemic dimension was increasingly recognised in the nineties, we note that several initiatives satisfy themselves with basing their analysis on a separation of three relatively dissociated pillars of SD: economy, environment, society. In each of the three, a large choice of indicators aims at satisfying the above mentioned principles.

Before describing the sub themes of the three dimensions, their content and logic, we discuss some major implications of these main principles on the objective of developing indicators: extension of the notion of progress to environment and social domains, inter and intra-generational equity, systems based approach.

Economic and environmental valuations

Research and empirical efforts to assess SD focussed on the difficulty to assess –piece by piece- the contribution to SD of the variation of environmental state and social context. The relatively strong convention in the economical sphere around Gross National Product (GNP) probably did not facilitate the efforts to valuate of other dimensions of SD. Evaluating the contribution of the state of the environment in terms of SD indices calls for mobilising a theory about the "value of environment". Becker (1997) and Geniaux (2001), among others, showed that an anthropocentric approach remains a more coherent choice than competing philosophies (theological argument whereby only the creator can sustain his creation;

pathocentric approach; biocentric individualism and biocentric holism that imply that non-humans are moral subjects carrying an intrinsic value (see Hampicke, 1994). The choice of anthropocentrism is clearly defined in the first paragraph of the Rio declaration: "human beings are the centre of concern for sustainable development". However, there is no globally satisfying method for delivering information on the intensity of human preferences about the value of environmental components. An important part of the debate, beyond the effectiveness of these methods, is over the question of knowing just to what limit substitutability should be the pivot in nature's evaluation (weak versus strong sustainability approach, compensatory versus non-compensatory aggregation).

Social progress : principles and indicators

There exists great diversity of theoretical foundations allowing different indicator choices to assess social progress and enhancement of individual and collective well being. Among these we can clearly identify **three principles** that has structured social indicator production in the SDI initiatives: intragenerational equity, satisfaction of basic needs and quality of life. The first principle deals with indicators of wealth distribution within a society, usually using the Gini, Herfindahl or Atkinson indices. The second one can be seen as a prerequisite to development itself, and indirectly participating to reducing pressure on natural resources. The third one which was expressed and acknowledged at a later stage than the others, is meant to remind us that sustainable development is part of a global progress perspective and does not only aim at sustaining an organising a production system. Moving from social acceptability to quality of life marks the transition from the status of prerequisite condition to the one of full component of sustainable development.

These two last principles have been very structuring on the social dimension of SD and on selected indicators in the different initiatives. Especially where basic needs are concerned, with quality of life generally coming down to a simple listing of socio economic variables leading to a rather inexplicit vision of what quality of life is, this in spite of strong demands for developing composite indicators in this category. One should indeed note that this evolution was imposed by the base (experience assessment, holist approach development). This prudent recourse to relatively autonomous socio-economic variables to account for quality of life can moreover be explained by the heterogeneity of cultural and legal contexts in which these variables evolve, making any measure fragile. Indeed the kind of all-enclosing concepts of "social capital" and "human capital" puts us in the larger context where the social and institutional components contributing to a better quality of life at both levels (individual, society) are included.

One of the founding principles of SD concerns intergenerational equity. Two philosophical principles support the interest for future generations. The first is Kant's categorical imperative, or ontological principle. The second is Rawls's theory of justice, which is more precise about the modalities of its operationalisation. Although they seem to fit as political principles, Rawls's theory ignores society's dynamic, so the problem of extrapolation from today's individual preferences arises. However, using the definition of justice suggested by Rawls (1971), we can define a particular criterion to maximise the utility of the least well endowed generation so as to respect an intergenerational equity constraint (Costes and al., 2003). Interestingly, this debate is essentially relevant for taking into account future generations when evaluating "benefits" or "well being" associated to different development paths or projects. Its formalisation, taking the form of actualisation rates, renders it limited to ACB approaches (monetary normalisation), and to issues dealing with sharing natural resource in time. In frameworks using indicator lists and where the appreciation of the contribution of an indicator to SD is left to the final user, it remains difficult to explicitly formalise taking intergenerational equity into account, other than case per case or by relatively loose rules. Moreover, few really normative approaches can be found accordingly in SDI initiatives, and intergenerational equity is in the end simply affirmed by accepting the that certain resources are important for future generations and should be taken into consideration by sustainability evaluation.

Pillars and stakeholders

The notion of "pillar" is frequently used do define the essential dimensions or themes of sustainable development. The large initiatives mainly refer to three pillars to account for sustainability: economy, environment and social concerns ("triple bottom line", with varying relative importance). In some initiatives, such as the capitals approach by the World Bank, the social pillar is divided into human capital and social capital. In the same way, initiatives that consider institutional issues sometimes include them in the social dimension whereas others make them a specific pillar. These pillars are then broken down into different themes, and this structure which precedes the choice of indicators is an essential stage in framework construction.

Framework evolution is best illustrated by the evolution of the components of the environmental pillar. One must indeed note that for lots of actors, the initiative to develop SD indicator was first initiated in relation to environment indicators. The way of structuring the themes of the environmental pillar, was therefore importantly affected by "methodological inheritance" form environmental impact evaluation, along natural sciences classical partitions of environment into "compartments". We thus start with a poorly structured list of environmental indicators by the OECD in the early nineties, and a systemisation of a biogeophysical definition of environment in main compartments: atmosphere, water, soil (land), biota. The main processes involved are in terms of pollution flows and resources stock and ratio of use (see OECD 1991 list in appendices 2.1.3.1 page 116).

As said in an OECD report (1998) « Initially many approaches to describing the environment were limited to information describing environmental quality and quality change, in terms of pollutant load or some other biochemical or biophysical indicators. However, it became apparent that while this might be directly linked to some specific change in the environment such as the loss of habitat or species, this sectoral approach did not necessarily support the decision maker in better management of the environmentally damaging activity. »

Shifts in environmental stakes and extension of SD initiatives

The increasing use of the PSR approach in the early nineties was therefore one of the ways enabling a double shift (Zuinen, 2004):

- from state indicators to a broader perspective accounting for phenomena at the origin of the evolution of these states as well as for modes of management and regulation of environment.
- from an approach focussing on environmental components to a more "environmental problematic" oriented approach.

This change in approach, expressed through PSR and its successors (DSR, DPSIR), with the search of causal links and the recourse to response indicators more directly linked to regulatory action, is also apparent in other initiatives. In such initiatives, the framework of stress-response type is not being used, there is a reforming of environmental compartments around environmental themes close to the problematisation mode, having its basis whether in environmental regulation or in NGO's (ecologists) instances. It also resulted in the restructuring of the environmental pillar into human activities. So from the middle of the nineties we find a reinterpretation of initial blocs (water, soil, air) into environmental issues (waste, biodiversity...) which are then crossed with sub-systems (forests, agricultural rangelands...), or a classification of resources that can be interpreted as revealing how environmental regulation is managed. We take as example the WB 1995 sustainability matrix (see appendices 2.1.4 page 122) who reinterprets blocs into problems of resource consumption (Sources), environment's purification services (Sink), habitat (life support), and sanitary effect (human health impact). Or, the same year with the propositions of the UN University (see Murcott, 1997), who crosses relevant ecosystems for environmental action with a list of environmental problems (landscape structure, production of goods and services, biodiversity, air quality, water quality...).

Other initiatives have integrally defined their classification and themes of SD indicators through political action modes, such as the European Union with Eurostat where structural indicators has been widely used. "Following United Nations' experience and recommendations, the commission conceived a framework relying on themes and sub themes directly associated to the priorities of the EU policies" (Almunia, 2005). The ten themes, that are recognised to be developed or amended in the future, are:

1) Economic development
2) Poverty and social exclusion
3) Ageing society
4) Public health
5) Climatic change and energy
6) Production and consumption modes
7) Natural resources management
8) Transports
9) Good governance
10) Global partnership

The present (December 2004) theme/sub-theme approach of UNCSD is a go-between these two tendencies because inside the decomposition of SD into four pillars, themes are defined with focus on policy issues within economy-social-institutional dimensions, while the environmental pillar is divided in mainly biogeophysical themes and policy issue sub themes.

Nonetheless, there has been a massive recourse to the PSR framework. Despite benefiting efforts that were made to structure indicators through a more problematic and policy issue vision, such efforts ignored that the underlying framework was incomplete: giving little information on the choice of dimensions, their relative importance, and not translating a defined vision of SD. As a result, any new issue was translated into a possible new indicator. This lead to an inflation in the number of indicators at the end of the nineties, which ended producing lists that were hardly readable and manageable in terms of global performance of economies in their SD perspective.

Though willingness to respect a parsimony principle figures in all initiatives, it was explicitly expressed through the research of key or headline indicators from 2000 on. In some cases, it lead to shrinking the final indicator list, in others to proposing different lists, keeping a large list accompanied by headline lists (CEI vs KEI for OECD 2003, see from pages 118 to 122).

Hierarchical and problem oriented indicators

It was the study of themes and classification of key indicators that resulted in this movement of recentering, and balancing of pillars and themes, to bring out the dominant themes:

Eurostat uses a "political problematic" classification (see appendices 2.1.2.1 page 108), and proposes a three level classification. The first level consist of 12 key indicators, destined to the public and high level political deciders, level 2 has 45 indicators, useful for evaluating political domains essential to SD and also for the public, the third level of 98 indicators corresponding to intervention domains and destined to a more specialised audience. Sub themes structuring level 2 gives a good idea of essential SD themes from a political intervention point of view (see appendices 2.1.2.1 page 108).

For others, the course isn't as clear. OECD stayed for a long time with pillars separating economy, environmental, social, and possibly institution, in its SDI. The end of the 1998-2001 mandate, they separates environmental, economic and human capitals under the theme of resources, and add a list of socio-economic variables under the theme of results.

During the 2001-2004 mandate, specific SD dimensions are essentially added to the environmental pillar (40 indicators among 69), and two other themes appear, with 5 indicators relative to pensions, and 14 relative to living levels in "developing" countries. This consists in an approach where pillars of SD only develop themes that are not in other indicator production initiatives: whether structural, but mainly environmental (CEI OECD 2004, appendices 2.1.3.3 page 118), or sectoral (such as the list of agri-environmental indicators, OECD 2001, appendices 2.2.1.1 page 127).

For the UNCSD (see appendices 2.1.1.3 page 106), we clearly have the 4 dimensions of SD in the lists, reducing from 132 SD indicators in the middle of the nineties, to a list of 59 from 2001 on. The social pillar is covered by 6 themes: equity, health, education, habitat, security and population, totalising 18 indicators within 12 sub-themes. The 5 compartments of environment are: atmosphere, land management, seas and coasts, freshwater and biological diversity, 18 indicators within 14 sub-themes. The two themes of the economic pillar are economic structures and modes of production and consumption, with 14 indicators set in 7 sub-themes. Finally, the institutional pillar adds two themes to the list: institutional frame and institutional capacity, 6 indicators in 6 sub-themes. We can note that in the majority of sub-themes a unique indicator was systematically chosen, contrary to the sub-themes of poverty, energy consumption and waste management differing with 3 or 4 indicators.

Balancing pillars

Original preoccupations of the logic behind SDI initiatives strongly condition equilibrium between pillars, the diversity and level of refinement within themes and sub-themes. We can distinguish initiatives building on general preoccupations on economic development (OECD, EU), from those more marked by specific development questions such as poverty (WB UNDP), alimentation and agriculture (FAO), and others clearly centred on environmental preoccupations (UNEP, FoE), with natural resources concern for some (WRI), nature conservation and protected areas for others (IUCN, WWF). Redifining Progress (RP) seems to position itself in the beginning on a more balanced status for the three pillars of SD. Indicators and thematic contents of each pillar in major SDI initiatives carried by these organisations are presented in appendices 2.1 and 2.2.

3 Indicators

3.1 Definitions of indicators and SDI frameworks

Indicators: definition, utilisation and interpretation

Indicators are quantitative tools that synthesise or simplify relevant data relative to the state or evolution of certain phenomena. They are tools for communication, evaluation and decision making that can take quantitative as well as qualitative form depending on the purpose of the indicators (Gallopin, 1997). The sustainable development indicators we consider here emerges form a particular class of indicators of progress, whose aim is to take into consideration sustainable development by integrating environmental, economic, social and human dimensions. Their technical and scientific content, which we will consider in this chapter, should not make us forget that indicators rest on conventions and that their legitimacy therefore builds on social conventions on what progress is and on how to evaluate it (Gadrey and Jany-Catrice, 2005). Such conventions are pre-requisite for the recognition and durable use of indicators or indices by various actors.

Relations between different variables used in indicator development are often represented with the help of the "information pyramid" (see Figure 1 below). This figure shows the different levels of aggregation and synthesis of information. On the first level, raw data consist of phenomena measurements (variables) in time and space for different populations. Then, indicators synthesise or simplify relevant data relative to the state or evolution of some phenomena. Some indicators are the result of aggregation, with or without weighting, of very diverse data and therefore carry a synthetic message. This is the case for instance with the Human Development Indicator calculated by the United Nations program for development, that aggregates 3 indicators (life expectancy at birth; educational attainment; GDP per capita). These aggregated indicators are also called indices (or index). When they aggregate indicators having different measuring units, they transform these indicators into indices (mapped indicators) to make measuring units disappear.

Indicators enable to represent and analyse a specific phenomena. Their signification is in principle larger than that of the variables composing them; and they permit to build a model that represents reality, but that is only a simplified image among others of this reality. The choice of indicators, as well as their *ex post* interpretation, are founded in at least partly subjective judgement, whereas their construction is a scientific and technical work. So indicator selection is partly a political activity.

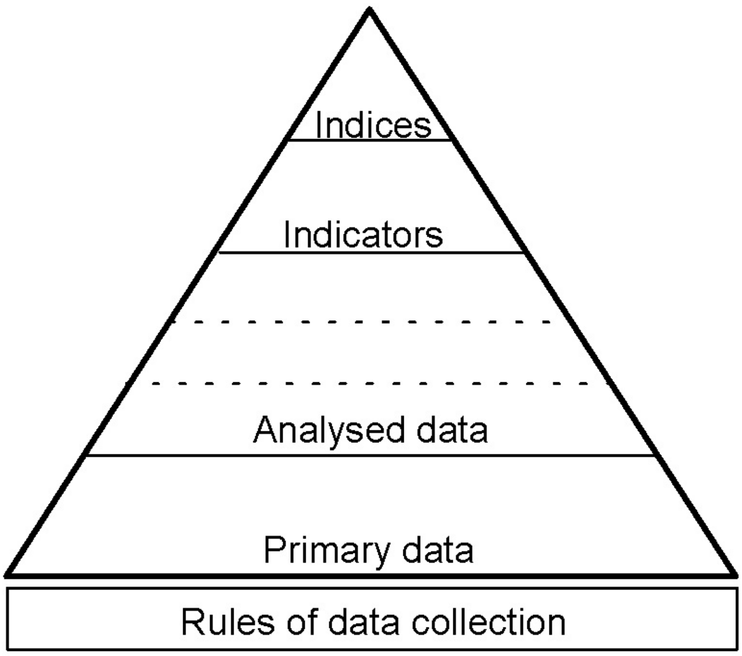

Figure 1 : Pyramid of information

Frameworks: linking SD principles with indicators, whether partially or completely

A SDI framework aims at translating a vision of sustainable development to an organising frame for indicator production. It organises the presentation of information relative to the different dimensions of sustainable development and their links, based on a set of principles forming the chosen SD vision. *"Instead of having a "one-problem, one-indicator" approach, SDI framework has to bring the economic, social and environmental aspects of society together, emphasising the links between them"* (Olsson and al., 2004). A SDIF thus has a double role, more or less balanced depending on the SDI initiative: to rationally answer the sustainability paradigm, and concretely organise the production of indices on the observed phenomena. When a real organizing frame is missing in the framework, one often finds in the process to design indicators a list of criteria for their selection. Such a process is more or less explicit and documented, and its role is usually more comprehensive than prescriptive. Examples of formalised processes are given in the next section. Conversely, when the framework is mainly devoted to organising indices, such as PSR and its derivatives (see section 4.1.1), the framework can be endorsed by projects having very different visions of sustainability. While mainly considering the outputs of the framework, end users (policymakers, politicians…) can overlook how such outputs depend on the conceptual model sustaining indicators development. This entails consequences on framework selection. A complete framework like (Bossel, 1999) system based approach (see section 4.1.4) remains hardly operational due to its high demand on integration. However, the "completeness" of the framework is an important aspect insofar as what it does not take account for will end up (or not) in an indicative list of criteria for indicator choice. An incomplete framework leaves in the end to much latitude into the indicator selection process, without ensuring that all dimensions of SD and certain links between them will really be accounted for.

3.2 Functions of indicators

A SDI is a quantitative tool enabling analysis of phenomena that concern sustainability of development, and their evolution. It thus has as a function to synthesise the information permitting to assess SD performance, with regard to states of various "dimensions" (man, society, economy, nature) and the evolution of states, taking place over different territorial entities. An SDI can also have the function of being an alert system by means of tendency prolongation, informed prospective or simulation.

Indicators can as well have a less territorial and more sectorial (or corporate) vocation, to evaluate the sustainability of sectorial policy, of a community's mode or project of management, of a business.

Finally, a related function to the two above concerns indicators link with action, and reactions to indices. Indicators, should point out, when possible, the associated actions and priorities within public policies (norms and rules, inciting policies,...) that could be carried out to modify the behaviour of the concerned categories of actor. Indicators can also have the function to facilitate auto-evaluation of sustainability of a production process or a practice for end-users.

3.3 Reference values: target, threshold and goals.

In an SD perspective an indicator without pre-specified value or without context has little meaning (Rigby and al., 2001). Thresholds, targets and benchmarks or reference levels are necessary to assess the contribution to SD of an indicator change. These references values can be expressed as a negative, a zero or a positive value in the indicator unit, and when the indicator passes this reference value, it reveals an unsustainable path. They are crucial in sustainability assessment of agro-ecological systems “given the propensity of ecological system to ‘flip’ from one state to another”(Moxey, 1998).

However, for numerous phenomena, it has been shown that establishing thresholds only with biological and physical criteria can turn out to be impossible or unsound (Pannell and Glenn, 2000). Today scientists’ definition of standard and reference levels is becoming less influential and the negotiated dimension of standards and reference levels in most of human activities is now widely accepted (Olsson, 2003). Indicators, with fix quantified goals, exceed the frame of scientific expertise and deal with political trade-offs between means and ends concerning problems related to sustainable development.

It may be difficult to produce absolute reference levels, coming from the scientific study of a phenomena or from negotiation processes. This can make approaches based on relative reference levels attractive. For instance, trend indicators are a way to relate the evolution of phenomena. More generally, based on relative or absolute levels, it is possible to rank territorial entities, from which relative targets can be defined as the distance to the best performance, the median or worst performance, …

Methodological aspects of these reference values are discussed in more detail for the agricultural problematic in chapter 5.

3.4 Indicators classes

There are different indicator typologies, but the one which has been most influential on different framework distinguishes list of indices from aggregated indicators and composite indicators. There is great variety within each category. In what follows, we mainly distinguish lists of indicators, who measure an indicator for each element of sustainable development with an appropriate unit, from aggregated indicators who combine in one indice (or sub-indice) different variables (or sub-indice) related to different dimensions of SD. Within aggregated indicators, one usually distinguishes composite indicators that aggregate different sub-indicators measured in distinct units, from simple aggregated indicators that involve measuring different phenomena with the same unit. In the first case, aggregation uses pondering so methodological choices are involved, whereas in the second case an evaluation theorization must be put forward (economic, biological, physical...).

In addition, although we will not develop this distinction in detail, one should clearly separate indicators based on objective data involving little value judgement on a lived situation, and data collected through survey involving opinions and feelings. If we take well-being indicators for example, an indicator of the first type can be rebuilt from these objective data, or it can be directly measured by an opinion survey.

3.4.1 Composite SDI

Composite indicators are based on sub-indicators that have no common meaningful unit of measurement and there is no obvious way of weighting these sub-indicators.

They normalise the judgement set upon the set of sub-indicators from which they are built and, by the reduction they operate, they facilitate global comparisons between territorial entities and communication to the public, as for example the Ecological Footprint index or the Human Development Index. However, this reduction implies information loss, which should be minimised. Applications to the thematic of sustainable development are also numerous (Saisana and Tarantola, 2002) and one can rely on an important literature. A specific development of this literature will be used in task 2.6, and we will here limit ourselves to only developing the most determining aspects for WP2 tasks involved in thematic indicators.

A formal presentation of this type of index ca be expressed as follows:

Composite indicator	$I = f(M)$
Dimensions	$M = (m_1, \ldots, m_k)$ *where* $m_k = h(Y)$
Sub-indicators	$Y = (y_1, \ldots, y_l)$ *where* $y_i = h(X)$
Variables	$X = (x_1, \ldots, x_n)$ *where* $x_i = g(Z)$
Data	$Z = (z_1, \ldots, z_p)$

Contrary to indicator lists where one usually considers that the users will be able to articulate a set of indicators to evaluate their contribution to SD, aggregation into a single index- or a limited number, one for each pillar for instance – imposed on composite indicators calls for an exhaustive explicitation of the potential contribution of an indicator to SD or to each SD pillar. Theoretically this means that whatever the value of each sub-indicator and whatever the value of other sub-indicators, the aggregation mode enables to attest the real "marginal contribution". To give a simple example, if the aggregated indicator is the simple sum of sub-indicators, this implies that whatever the level of each sub-indicator the contribution of a supplementary unit of each sub-indicator is constant, or positive or negative, and that indicators are independent between themselves in their contribution to sustainable development (no cross effects). This condition is naturally inconceivable given the complexity of the problem, but it remains an ideal objective. Without fixing such a constraining frame the following should be ensured:

- make variation ranges of sub-indicators comparable,
- that a consensus emerges, for each retained indicator –in literature or among SEAMLESS participants, on a univocal, that is positive or negative, contribution to SD or SD pillar. If such a consensus is not reached, the sub-indicator can be used if threshold values changing its contribution to SD are identifiable.

This last constraint is by the way a simple mean to avoid the explosion of the number of indicators in SDI initiatives.

We will analyse here a certain number of methodological aspects because this type of indicator regroups the range of difficulties other indicators face. This analysis will rely essentially on works lead within 2005ESI which is a reference where quality in the methodological treatment of each step of composite indicator construction is concerned.

One of the first methodological determinants is knowing whether the ultimate objective is to enable ranking of different countries or regions or obtain an index. Clearly SEAMLESS should enable to compare different policy options in a determined region, which implies that the final output cannot be only such a ranking and invalidates certain methodological options.

Seven steps are generally distinguished:

- Choice of variables: this step aims at determining the variables that will enter the construction: deliberate choice, relying on a list of criteria involving availability of data, quality, comparability, scientific pertinence, and/or relying on statistical multivariate analysis (correlation analysis, principal component analysis, Factor analysis, Cronbach's alpha, Cluster analysis). It also aims at choosing the unit in which a variable is expressed.
- Imputation mode: missing data may introduce distortions in the information vehiculed by the indicator. The choice of imputing data or not and of the eventual imputation method determines, in part, the quality of the indicator. At the heart of imputation methods intervenes the identification of the statistical properties of the missing data. They can for instance correspond to a MAR process (the distribution of missing data doesn't depend on the results associated to missing data), or MCAR (particular MAR case where the probability that a value is missing is random). Relying on hypothesis on these proprieties, different statistical methods enable to impute values to missing values from the analysis of the set of data (example of techniques: listwise deletion, Last value carried forward, Hot desk closest match, average closest match, Expectation-Maximum algorithm, multiple Imputation (see Conway, 1993b; Fairclough, 1998; Little and Rubin, 2002).
- Transformation and normalization: one can apply a mathematical transformation to data in order to gives it desirable statistical proprieties (homoscedasticity, normality, reduction of outliers, non-colinearity). Salzman (2003) identifies several possible techniques for standardization: no standardization (justifiable essentially with ratios), normalization by Z-score or gaussian normalization, LST(rescalling), ratio percentage and distance to target, satisfaction level stated by experts.

- aggregation : aggregation can than be additive, multiplicative or put to a power and also involves fixing a method to determine the weights assigned to each sub-indicator. Some discrete rules (lexicographic, weak link, number of sub-indicators below thresholds, …) can also be used to assess sustainability index in a more strong sustainability perspective.
- Evaluation: sensibility analysis and uncertainty analysis. Using sensitivity analysis, we can study how variations in the composite index derive from different sources of variation in the assumptions. Sensitivity analysis also demonstrates how each indicator depends upon the information that composes it.
- *ex post* statistical inference. In this stage where *ex post* means that the composite indicator has been calculated, statistical inference tools can be used to identify the relation between the composite (or some transformation of it) and a set of contextual variables not included for different reasons in the composite. 2005ESI (Esty and al., 2005) for example, also identify what are the included variables that infer mostly on the ranking results.
- Choice of the visualization method.

See Appendices 1 page 99 for more details on methodological aspects.

3.4.2 One unit aggregated SDI

The design of aggregated SDIs entails measuring, in a single physical or monetary final unit, the different phenomena considered. Aggregated indicators therefore call for a theoretical and methodological framing (natural sciences, physical sciences, sociology or economy) to operate the transition to a common measuring unit. On the other hand, by requesting a same unit, it simplifies the considerations discussed above.

One can distinguish two types of aggregated indicators: those passing through a monetarisation of non-market goods and services, examples of this type of indicators is GPI (Genuine Progress Indicator), and other indicators relying on the aggregation in physical terms of resource use, such as Ecological Footprint (EF). In both cases the question as to what phenomena can be apprehended through this type of normalization arises. For instance, the EF aims at measuring in a single unit expressed in a geographical surface, the biologically productive area required to produce the natural resources that an entity (community, region, city, individual) consumes, expressed in global square meters. It is based on a number of assumptions about sustainable technology, to transform environmental degradation and resources consumption into surface (see section 4.2 for detail).

Despite the numerous desirable properties of this index, that we will discuss later, the sustainable development dimensions it can account for is limited since it only concerns environmental degradation and resource consumption.

When using monetarisation, three approaches are possible:

- to measure market or near-market values and thus underestimate the total value of non-market goods and services,
- to measure total values that are established by an expert panel,
- to use valuation methods for non-market goods.

Only the third approach calls for an explanation. These methods rely on identification of consent to pay (or receive) by individuals to benefit (or cease benefiting) from a non-market good or service, generally environmental, even though there exist a few examples in the social field. Such valuation methods are whether based (i) on behavioural intentions in hypothetical situations provoking trade-offs between non-market goods and money – Contingent Valuation Method (or non-market good-Conjoint Analysis)-, or (ii) on analysis of the market of complementary goods or substitutes – Cost Travel Method, hedonic Method, Mitigation Costs Method-, like for instance money spent to get to a natural site. Even though their use is justifiable from a theoretical point of view, their results are weak depending on the nature of measured goods and services. Some examples can be found in the following fields:

- individual familiarity with goods and services proposed to evaluation (Heberlein, 1988),
- perception of financing modus and public action modalities (Geniaux, 2001) and/or
- quality of implementation of methods (ability to reduce methodological bias, see Mitchell and Carlson 1989 and context effects in Brown and Slovic, 1988).

In addition to doubts about validity measures dedicated to given and contextualized components of environment, the harshness of these methods (technical and financial) in large scale initiatives (regional or supra) imposes important recourse to transfer of values between components judged comparable or between measures taken in different places and contexts, which make results that much more opaque and unreliable.

The most known indices such as ISEW (Index of Sustainable Economic Welfare), GPI (Genuine Progress Indicator), GSR (Genuine Savings Rate), use the two first approaches essentially privileging evaluation of the market values of the considered environmental and social components (Lawn, 2003).

3.4.3 Lists of indicators and dashboards

An indicator list is a set of indicators measured in units appropriate to the considered phenomena. These lists are generally ordered in themes and sub themes, so as to enhance legibility of the performance of a nation or a region in the different dimensions of sustainable development. Indicator lists remain the most common used in SDI initiatives), even though they catch less attention from media and public, as compared with EF.

The principal advantages explaining the preference for these types of lists in SDI initiatives are:

- the ability to produce information for those who make the decisions Decision makers receive information directly centred on their domain of action and potentially on evaluation of their past actions,
- they comply with multi-disciplinary and not necessarily inter-disciplinary approaches, possibly skipping the work of conceiving a real framework,
- lastly, they enable the implementation of substitutability hypothesis between certain components of sustainable development. And substitutability constitutes for certain frameworks a condition for addressing SD issues.

One of the principal shortcomings of these lists is the inflation of the number of indicators over time. The reason for this inflation is that this type of approach implicitly aims at completeness without a clear definition of essential and universal properties of SD. Inflation is a result of the fact that it is always possible to identify new components of SD which is not represented in the existing list. This problem naturally grows in large scale initiatives with great diversity of environmental, social, institutional and political contexts. Lists also make global performance for a country or a region complex to appreciate, as far as SD is concerned.

System-based approaches on the other hand define a set of properties essential to the desired viability of the considered system (country, farm, cow...), and for other vitally related systems, so it is an organising means that avoids repetition and is limited by the number of included systems. However systematic study of interrelations can be a heavy burden.

System-based approaches indeed allow to avoid one of the recurrent flaws of aggregation, being that the loss of an essential element of SD can be compensated by another without any clear expression .

4 Main Frameworks

The main frameworks are described in four sections by identifying their organising principles. In a first section, we present frameworks leading to indicator lists. They differ from those used for aggregated or composite indicators, introduced in a second section. In a third section some agricultural and rural specific frameworks are proposed. The fourth section presents and discusses transversal concepts of SD that did not lead to a formal and applied SDI framework but contribute to our objective in SEAMLESS.

4.1 SDI using list of indicators

4.1.1 The PSR, DPSIR, DSR approaches

The "P-S-R" or " Pressure-State-Response" framework was elaborated in the 80's to organize environmental analysis into causal chains: centred on the state of environment, pressure is seen as exerted by human activity through pollution flows and resource consumption, while Response encloses societal measures taken in reaction to the state or change of state of the environment. (see OECD lists page **Error! Bookmark not defined.** to 122)

This framework was later refined into the "D-P-S-I-R" or "Driving forces-Pressure-State-Impact-Response" model. Here, an attempt is made to distinguish the cause of the pressure on environment, human activity mainly through consumption and production (Energy consumption,...), from the pressure itself (CO2 emissions for instance). A difference is made between the state of the environment, of a particular stock, and the impact it has on other stocks within environment or other dimensions (pollution's impact on human health for instance). Note that identifying indicators to these categories is not always straightforward. Nutrient balances, for example, might be a pressure indicator, but could similarly also be identified as an impact indicator.

An advantage of this family of frameworks is that causal chains are easy to conceive, and are particularly adapted to some straightforward interactions between economy and environment. Stocks and flows can be treated correctly within the chain. Another central feature of this approach is that, economic activity is identified as the main driving force. So responsibility is clearly put on consumption and production modes, as suggested by principles 7 and 8 of the Rio Declaration. This serves policy oriented thinking, and gives a place for the institutional dimension.

However, the limitations of PSR were only partly, and for some not at all, answered by its derived successors. These frameworks organise causes and effects of environmental state or changes, this implicitly emphasise the environmental dimension of sustainable development. If these initiatives were to put economy in the centre, influencing factors (general economic trends, sociological situation...) would not so simply fit into this type of causal chain. Furthermore, while the introduction of impacts can show some consequences of environmental damage on individuals and society, social condition (poverty) often influences this damage but through economic activity, thus the link is too indirect to be clearly taken into consideration by these frameworks. In general, the framework is adapted to situations where environment is at stake. In these situations types of pressures are identified: specific (e.g.: use of N fertilisers in nitrate pollution…); straightforward (no multiple causes creating different equilibriums among non-linear interactions); impacts are not important indirect causes for further degradation; sectors of activity where efficient measures can be taken are pre-determined (e.g.: agriculture, industry…)...

In our discussion, the fact that this simplifying model misses some complexity and some phenomena is an important part of its general shortcoming. Basically, apart from implicit emphasis on environment, the PSR model gives no hint to what it is important to look at, what balance should be found between dimensions of sustainable development, or even between environmental issues, and why certain links are important or not. As discussed in preceding sections, it is not an indicator framework translating a vision of sustainable development, except for communicating the minimum common agreement that there is a problem with man's use of environment. This explains why PSR-type chains are used in initiatives lacking such a vision and having very different normative goals.

Finally, because causal chains fit well into a sectoral breakdown of issues, simply by splitting pressures, PSR tends to advantage sectoral policies. Although this may be positive side of the approach, this can miss the SD objective as a whole, requiring policies across sectors concerning consumption, production and trade.

4.1.2 Capital-based approach

In a SD perspective, it is essential to have an equally balanced approach between the 3 dimensions of SD: social dimension, economic dimension and environmental dimension. Only such an approach enable to systematically emphasise interdependence relations between them, without under-estimating either one. "*To make SD more concrete, several writers have transformed these pillars into different types of capitals to be able to more easily illustrate the linkages and trade-offs between them (Bossel (Bossel, 1999), 1999). A frequent classification is four types of capital, namely, manufactured capital, natural capital, human capital and social capital (Daly, 1990; European Commission, 2002)*" (Olsson *and al.*, 2004).

This classification plays an important role in equilibrating dimension, but leaves much flexibility in defining the contents of each capital. In this approach it is essential to precise the dominant interpretation of the notion of human, natural, social and economic capital. Following Schuller (2000), Human capital concerns essentially economic behaviour of individuals, especially the accumulation of competence and knowledge serving their productivity and income. It can thus integrate certain indicator on necessary means and conditions for this accumulation (health, well-being).

Social capital involves in particular networks, interpersonal relations, as well as shared social norms and values they go by. It can be defined at community level, or other entities. Woolcock and Narayan (2000) differentiate bonding social capital (relatives and close friends) and bridging social capital (acquaintances, other social groups). When considered as a stock of social resources, it is also distinguished from capacity, i.e. the ability to draw on capital for valued purposes. However, social capital is not always attached to a positive view: mutually supportive interpersonal relationships within a network or community may be accompanied by prejudice or hostility towards outsiders; resources can also be "objects of struggle" between individuals and families. Finally, the possible distinction between social and institutional capital is often blurred in practice. Social capital would have a privileged position in discussions on sustainability, namely facilitating the creation or use of other types of capital.

4.1.3 SEEA

The System of integrated Environmental and Economic Accounting (SEEA) is based on an enlarged national account. It origin can be found in the work of UNEP and the WB, which was formalised in 1993 in the "Integrated Environmental an Economic Accounting" handbook". It develops a satellite system of the System of National Account (SNA) with a specific focus on the links between economy and environment. It is presented by its developer to be more flexible because of the use of different statistics modules using both physical and monetary units. The main differences with other lists of indicators is that it:

- focuses on an elaboration of "all" environment-related flows and stocks,
- provides a linkage of physical and monetary accounts,
- constructs modules with systematic monetary evaluation of man-made and natural capital, and environmental costs using the link between physical and economic assets, and provide an estimation of the environmental protection expenditures (Alfieri, 2000),
- proposes an environmental adjusted national wealth and some other aggregated indicators in its lists.

The latter indicators are calculated by subtracting depletion and damage cost from the economic indicators. The most currently used indicators are the EVA (Environmentaly-adjusted value added), EDP (net domestic product), and ECF (capital formation). A detailed document on implementation of this framework can be found in (UN and al., 2003).

The main limits of this framework are the same as for other frameworks using monetary evaluation of environmental benefits (see section 3.4.2). Another problem is that some attempts of damage valuation have been systemically excluded because they were seen as too controversial. Moreover, these types of approaches has a complicated organisation of satellite systems and deals exclusively with physical supports of production, of consumption, and of environment (accounting approach of resources). This hampers interpretation in terms of well-being or any measure of quality of life linked to socio-economic variables non expressible in resource units. This framework also remains ambiguous concerning the coupling between the monetary and physical units, since it is based on a strong substitutability principle to define resource depletion in physical terms, but uses monetary evaluation of these losses in other modules, thus mobilising a weak substitutability principle. Finally, this framework does not provide directly SDI, but may be used as a database or as intermediate indicators.

The main advantage of this types of approaches is that they provide a tool that enables to highlight (partly at least) interrelations between human activities and resource depletion, by identifying these links.

4.1.4 System-based approach

4.1.4.1 Systems approach and modelling

A systems approach to sustainable development is of interest because through its construction it enables to explicit what features are considered essential to SD, and it provides an organization for an indicator set following these features.

Complex dynamic systems and their interactions have been studied at length, in many areas of science, and theories accompanying a body of organisational principles have emerged independently of their particular setting (Ewert and al., 2005). A review of its application to ecosystems is presented in Becker (1997). Bossel (1999) exposes a systems framework and method for deriving sustainable development indicators, which will be commented here.

A system is an entity composed of elements structured in some way (a person, a community, a car...), with a boundary defining exchanges between interior and the **system's environment**, i.e. its exterior.

The first step in deriving an indicator set for sustainable development is:

- Defining the scope and purpose of the study. This involves determining what is the system to be studied, which we will call the total system, its boundary (spatial area, nature of the concerned system). What is exterior to this system may be accounted for with less importance than the system itself, so this subjective choice is important.
- Then a modelling of the total system (ex: human society in its environment in Europe) has to be determined. First, relevant subsystems should be identified, that are parts of the total system having essential meaning relatively to its functioning (ex: economy, environment, society).

  Among them a particular subsystem can carry the prioritary objectives of the study (ex: European society); the other subsystems, and the total system seen as embedding this particular subsystem are then essentially supports for it. Note that identifying if such a subsystem is pertinent, or if on the contrary all subsystems have the same status and should be sustainable for their own sake (hence the total system also) reflects particular visions of SD. For instance, the natural environment can be viewed as supporting the human society, or its development can be pursued also independently of its utility to humans. Anthropocentrism was identified in Becker (1997) as the only widely accepted basis for SD, with the argument that it enables to consider environmental preservation for its own anthropocentered reasons. Bossel (1999) comes to an analogue conclusion, and suggests that the indicator set should, whatever the ideological background, cover the widest horizon of attention, though some indicators may not reflect actual priorities or dominant values.
- Finally, subsystems and their relative importance is also determined by choosing what essential relations between them are accounted for.

The choice of essential supporting systems and the model for the total system are also subjective. This choice can emphasise or neglect:

- certain relations (advantaged or not by the chosen subdivision),
- certain types of relations (decision making, sociological, environmental, economic...), adapted or not to the scale of the subsystem.

4.1.4.2 Matching a system to its environment: properties and basic orientors

Once the total system, its essential subsystems and their relations are determined, the second step consist in choosing the properties these systems should bear to be sustainable. Bossel (1999) argues that human society cannot be static, so its viability has to encompass development, which is seen as equivalent to sustainable development. Following the orientation theory (Bossel, 1999, 2002), the properties of its environment shapes how a dynamic system is structured and how it behaves. Indeed, the system orients its structure, function and behaviour to adapt and take advantage of exterior and interior conditions. The theory identifies six universal properties (supposed to be non-redundant and cover all situations) of a system's environment. So six corresponding orientors, meaning corresponding categories of concern for the system to deal with its environment, are derived. A psychological needs orientor, being a concern for sentient beings (system-determined, as opposed to environment-determined) is necessary for human related systems. These seven orientors, presented below, will be represented by relevant indicators representing the system's answer to the concern in a particular situation. They are supposed to cover all eventual viability concerns for all systems:

- Existence. The system must be compatible with and able to exist in the normal environmental state. The information, energy, and material inputs needed to sustain the system must be available.
- Effectiveness. The system should, on balance over the long term, be effective (not necessarily efficient) in its efforts to secure required scarce resources (information, matter, energy) and to exert influence on its environment when necessary.
- Freedom of action. The system must have the ability to cope in various ways with the challenges posed by environmental variety.
- Security The system must be able to protect itself from the detrimental effects of environmental variability, i.e., variable, fluctuating, and unpredictable conditions outside the normal environmental state.
- Adaptability The system should be able to learn, adapt, and self-organize to generate more appropriate responses to the challenges posed by environmental change.
- Coexistence. The system must be able to modify its behaviour to respond appropriately to the behaviour of the other systems in its environment.
- Psychological needs. These constitute an additional orientor for sentient beings.

So the choice of properties can:

- resume to these universal basic orientors for each system, those of them that are relevant (some simple subsystems do not deal with their entire environment),
- be chosen following the interest of the indicator set producer, using or not the universal orientors presented by Bossel (1999).

Note that the main interest of this systems approach is its attempt to universality, ensuring that no vital area of sustainability of a system is neglected. Furthermore, the use of these orientors is unique, not that there doesn't exist other sets of orientors, but because each orientor is necessary in that it covers concerns ignored by the other six orientors . So choosing the option of using the orientor set takes subjectivity out of this step (apart from accepting the pretended universality).

4.1.4.3 Using basic orientors to guide indicator selection

The third step is identifying indicators. A main principle in systems analysis is that the total system is viable only if all subsystems are. This leads to deriving representative indicators of the basic orientors of (or the properties assigned to) all systems (total system, other essential subsystems), and indicators of the participation of each subsystem to the basic orientors of the total system. If one indicator is chosen for each basic orientor, this leads to a maximum of 14 times the number of subsystems, plus seven for the total system which is limited, but still numerous.

Even though indicator choice is subjective, all areas of sustainability are covered. If indicators are relevant, the sustainability assessment should be relatively independent of their particular choice.

The indicator set is designed for the purpose of determining if the total system is sustainable(we can take advantage of it for other purposes, as we will see below): all orientors will have to satisfy a determined minimum satisfaction (corresponding to an indicator threshold) to ensure sustainability. If one orientor is bad off, the whole system is unsustainable. This implies that trade-offs between minimum satisfaction of different orientors is impossible. And only when basic satisfaction for any defecting orientor is ensured, should one be preoccupied with ameliorating other performance. However, this systems approach ensures "all" important questions are addressed concerning the viability of the system model (meaning the subsystems chosen). So it is also a way of being eventually complete in deriving an indicator set, of determining what relations are considered important. The particular choice of indicators can than be chosen to address only the orientors considered relevant, and with diverse purposes in mind such as policy relevance, early warning, aggregation or policy comparison... The following points should be kept in mind:

- Indicators should account for the links between subsystems: for this a systematic review of the participation of a subsystem to the basic orientors of another can be conducted. The chosen indicators should highlight these links.
- If one indicator per orientor is chosen, it can be because: it is a good representative of the corresponding properties, it represents the weakest point, it is an aggregation of representative indicators (and/or other criteria, depending on the purpose of the study, sustainability assessment or other).
- Indicator's scope should be clearly presented, only its participation to the considered orientor should be assessed, even when it can be related to another orientor.

4.1.4.4 Assessing viability and performance

This leads to the fourth step: assessment of basic orientor satisfaction, that is quantifying the indicator's participation to sustainable development.

This can be done thoroughly, for instance by determining assessment functions mapping indicator performance onto an orientor satisfaction scale, with at least one threshold corresponding to basic satisfaction. It can also and often has to be done less precisely, the sustainability diagnostic depending only on evaluation of basic satisfaction of all orientors of all systems.

The choice of these assessment functions, and the breaking points for indicator values, the point where the contribution of the indicator to orientor satisfaction changes (in value, in rate..) are subjective. However, the notion of what is satisfactory should be related to properties such as adaptativity, which then are considered independently, so assessment functions should be free of trade-off considerations.

To **summarise**, the systems approach has the following characteristics:

- it is systematic, so a complete view of SD is searched for, and the areas where indicators, thresholds, breaking points or data are missing are explicited,
- it is a construction, so steps where subjective choice is made can be broken down and made apparent,
- it supposes a model of interacting subsystems is derived, so their functioning is researched, and interactions are emphasized,

- within this construction which reflects the chosen vision of SD, a straightforward organization for the indicator set is given,
- assessment of SD is simple: all indicators have to be above a determined threshold, if not the whole system is unsustainable, no trade-offs are possible between the system's basic orientors. On the other hand, for comparing different policy options for instance, indicators have to be chosen that highlight their advantages and shortcomings, the thresholds being of less central importance.
- the indicators are relative to general functions of a system, so, a priori, policy relevance (understood as interpretable for decision making), even though the subsystem choice can be related, has to be kept in mind and ensured when choosing the particular indicator.
- Sustainability is assessed through general properties, indicating areas and concerns to be considered. The indicators that will represent them can be chosen to account for a particular context, and Bossel 1999 provides guidance on participative methods to seize such a context.

4.1.4.5 Why the system approach can help us design a framework

It seems interesting to discuss how a system based approach allows to treat certain elements that the WP2 SEAMLESS Framework has to deal with : scales, sectors, rurality and policy relevance.

First, the definition of the studied system influences how these elements intervene. For instance, we can assume that sustainable development is our objective, and that we want to build an indicator set for Europe. Sustainable development of Europe (our system) can be set as the primary goal, with consequences on its world environment assessed in a more or less organized manner since it is exterior to the considered system, taking for granted a number of trade, economic, and other world wide functions (that do not depend only on Europe). This will lead to a set of indicators different than that derived, for Europe, from a world sustainable development point of view. In the latter, the world SD is the goal and the world our system, and how Europe finds its place within this goal will shape a European indicator set.

System and scale

This is true whatever the option is from a world point of view. The first option is to consider a framework for world SD (or whatever other purpose at world scale), and then a framework for Europe's SD within paths compatible with the first one, making an SD assessment at different scales (the link between scales to be determined). The second is to consider a framework for world SD, and make Europe a subsystem of the world, then having a systemic relation between both scales: the participation of Europe to the orientors of world sustainability.

Whatever the purpose, SD assessment or other, whether the smaller scale should be treated as a subsystem of the larger is a question. Note that in Bossel (1999) the scale is specific and the notion of subsystem is used at whatever scale for domains or dimensions of SD; this is more directly similar to considering a sector of these dimensions as a subsystem in a sectoral approach.

The same thing is of course relevant when considering the European level related to lower levels (in scale), such as country, region, etc. What territorial entities should be used as a studied system in SEAMLESS, with a complete individual framework for its set of indicators?

Moreover, if sub-sectors and/or smaller scale regions are to be fully assessed, new indicators may be needed, possibly they will not just be an adaptation of the types of indicators figuring in the higher level sets (such as looking at a particular type of event in a region where it is traditional, as revealing importance of cultural activity; versus assessing rurality functions, that can be relevant only at a community level, and not at higher levels).

So it seems pertinent that a framework be designed that can thoroughly analyse the sustainability questions specifically at each scale, or at some important scales.

System and Sectors

The definition of the system also has consequences on the sectoral approach. Indeed, at any scale, sustainability of agriculture (our system is then the agricultural system) versus place of agriculture within the sustainability of its imbedding community (our system is then a village, a region, a country..) are hopefully not incompatible. But different interest will hardly give a same indicator set, and the systems framework construction enables to translate this difference.

If the starting point of SEAMLESS is sustainable development of agriculture in Europe, meaning the studied system is the agricultural sector, the same discussion and choice has to be made concerning sub-sectors relevant to the different issues (sugar beat issue, different agricultural systems...). Should sub-sectors be assessed completely and individually, deriving as many thorough sets as necessary; are they subsystems to the agricultural system?

System and rurality

The concept of rurality is put forward in SEAMLESS. It can be defined relatively to a spatial area imbedding agriculture, having characteristics of land use, or relatively to a community living in such an environment, and having particular sociological functioning.

The meaning of rurality has to be defined in SEAMLESS. On the one hand, if rurality is defined as a specific area, for instance land cover discriminating rural from semi-urban from urban area, pertinent as for as agricultural land is valuated, is this definition compatible with available data for all EU countries ? On the other hand, if rurality is defined as functions of a community in rural area, exceeding land management, what is the relevant community and do we have data for such community?

As will be presented below, we consider the heart of rurality to naturally take place at the level of community (village scale in France…). At this scale the concrete relations between people living in the same community take place, with particular tensions (in particular between farmers and other inhabitants).

In the framework proposed in the last chapter we distinguish, at all territorial scales, and within the total system (the region and its inhabitants at regional scale), an agricultural system: it encompasses the agricultural land, the people working or living on this land and their families. Both systems and their respective logic, agricultural system maintenance and sustainable development, are articulated. At farm scale, the total system is the agricultural system (not territorially defined), so issues related to the more general sustainable development perspective are only indirectly modelled considered, through the eye of agricultural maintenance, or in the link (to be modelled) of this scale with the larger territorial scales. This is why the community level, defined as the first available elective entity, is important. Hence at community level, the total system is the community, and within it the agricultural system is assessed, but also the sector's relation to the whole community through its participation to the sustainable development properties of the community. Not only is this the scale of direct "physical" interaction, but the contribution of the agricultural system to sustainable development is mainly dedicated to such interaction. At higher territorial scales, the contribution to sustainable development will also have to consider and emphasize other questions such as rural-urban relations, regional balance between activities... Because this scale may be skipped in SEAMLESS for lack of data, we suggest how to possibly account for some of it at regional scale.

This community level is also the smallest entity where all functions of human society can be found, following Bossel (1999).

A difference can also be made between functions (environmental management) and activities (farming) that are specific to communities in rural area, and the functions and activities that exist everywhere but are influenced by the fact of taking place in a rural setting (water use, public services, land use planning...). These issues are within SEAMLESS scope as they are influenced directly by CAP policies as well as all environmental policies. The indirect consequences are also important because rurality deals with the closely meshed agricultural practice and social construction (modes of social reproduction, local political power of agricultural sector, dependent on the type of farming system and farmer’s origin ...).

System and policy relevance

If policy relevance is the fact that an indicator gives information on a phenomenon that can be influenced through known political initiatives, it is a desirable feature for indicators, but should pertinence and completeness of the systems approach be sacrificed to it? This type of policy relevance is a criteria that is often evoked as desirable if not necessary when choosing individual indicators. But it can also reduce the scope of the indicator assessment, concentrating on areas and issues we have responses for, instead of completeness criteria. The P-S-R type framework has a natural setting for policy relevant indicators with response indicators, whereas this criteria usually has to be checked individually in choosing particular indicators. In the case of the (complete) system-based approach this can be done when determining representative indicators for the system orientors.

Policy relevance can also mean that globally the indicator set should assess if policies have a positive action on sustainability concerns or contrary. This can be attempted by integrating in the set a number of indicators relative to policies, still fulfilling the above criteria for individual indicator choice. But, this seems unsuitable to compare different options of any particular policy. Since comparing the merits of competing policy options within the CAP is a desired feature in SEAMLESS, we propose that it be integrated in the framework by ensuring that every indicator representing properties is chosen for its importance in comparing aspects of the concerned policies. This is possible because a framework based on universal orientors (properties) is thought to be adaptable for any system, at whatever scale and in whatever particular purpose. So instead of having a set of indicators in which different issues and policies are represented by a number of respective indicators, it is possible consider each policy separately: all indicators representing the properties in the framework are chosen to assess this particular policy (to compare options of the policy for instance).

4.1.5 EUS (Environmental Utilization Space) and Ecospace

The origin of this framework goes back to works of Horst Siebert in 1982, and application to SD in (Opschoor, 1992; Opschoor, 1987). Ecospace uses a spatial equity principle in the usage of resource and their degradation. It claims that all individuals have the same right to use an equal amount of natural resources and to pollute the global commons. According to Hans Opschoor, ecospace is a metaphor to capture the notion of limits and the need for redistribution of access to resources (OECD 1998, Rosenthal workshop). Unlike direct application of the carrying capacity concept, measures of EUS or Ecospace have to account for human demand and its evolution. This can be for example, in the definition of "functional unit" which measures the size of a resource, modified according to the (competing) demands made on it and the quality required accordingly.

FoE Europe uses this framework with a “physical” focus and proposes some reference levels for the North industrialised nations to allow the developing south nations to reach acceptable development standards. Indicators in construction deals with the environmental performance of input resources with a reference reduction factor of 4 for the greenhouse gases (based on calculations that greenhouse gas emissions will double over the next fifty years) and reduction factor of 10 for the consumption of natural resources. This is based on a per capita consumption of natural resources that is about five times higher in OECD countries than in developing countries, which mean that a sustainable level of material turnover is only attainable if OECD countries reduce their resource consumption by a factor of ten (Spapens and Buitenkamp, 2001).

4.1.6 Land quality, land use and land value analysis

The central resource for agriculture is the soil, this resource is the focus of certain frameworks. Some of them are based on land quality indicators. As mentioned in Bindraban and al. (1999) (“Land quality refers to the condition and capacity of land, including its soil, weather, and biological properties, for purposes of production, conservation, and environmental management (Pieri and al., 1995) Maintenance of the agricultural production capacity of land resources is a fundamental element in the discussion on sustainable land use. Changes in land quality should be monitored to provide early warning of adverse trends and to identify problem areas. Monitoring land quality and promotion of land management practices that ensure production and sustainable use of land resources require development of quantitative Land Quality Indicators (LQI) (Pieri *and al.*, 1995).”

Some Frameworks hence articulate their sustainability evaluation system around indicators directly related to this resource: some are based on land use, classified in broad categories, others are indicators of land quality, and the more complex frameworks deal with agricultural practices or their impacts (Darwin and al., 1996). Just as Sustainable Rural Livelihood (SRL, see page 64) framework, some of these frameworks enable to deal with rural/urban relation, particularly in concurrent usage phenomena. They are perhaps the frameworks where the use of models (agricultural, agro-ecological) in SDIF is the easiest. This should be considered in relation with WP3.

If we assume that agricultural land use is preferable to industrial or urban use from an environmental perspective, agricultural surface in activity can be a first level indicator for SD. This is particularly relevant when agricultural areas are coupled with indicators classifying agricultural practices by their diverse respect of environment, as implemented in some vulnerable zones (Bellon and al., 2000). These two types of indicators are pressure indicators. Conversely, indicators of LQI type, are state indicators susceptible to participate in ranking agricultural practices relatively to sustainable development.

An interesting framework than can be used with land cover data is based on **Ecosystem Service Product (ESP)** concept (Costanza and al., 1997; Sutton and Costanza, 2002). In this approach, seventeen land cover classes representing the major biomes of the world where defined using GIS technology (IGBP data with 1 Km2 resolution) and linked to the value, in terms of **ESP**, as estimated in Costanza *and al.* (1997). It seem suitable to deal with the spatial organization of ecosystems at large scale using a limited class of ecosystem, but some development would be necessary to take into account diversity of agricultural lands. The ESP value can be improved by farm level analysis of environmental impact in order to describe better the links between agricultural practices and functional services of ecosystem connected to agricultural land.

4.1.7 Material Flow Analysis (MFA), Substance Flow Analysis (SFA) and Life Cycle Assessment (LCA)

Numerous SDI Frameworks are based on physical accounts of energy or material flows. They can be included in quantified tools of physical economy approaches and are based on the concept of physical economy of humankind (Ayres, 1998). As Daniels and Moore (2002) point out, "Physical economy approaches exist as evidence of the inadequacy or incompleteness of monetary measures of the parameters of the relationship between the human economy and its habitat." Since several decades, the importance of identifying and tracing physical flows of materials and energy, and not only monetary flows, is well known (Ayres and Ayres, 1970, Georgescu-Roegen, 1971, Leontief, 1970). Moreover, the growing concern of environment degradation, and the large reconnaissance of sustainability principles has since the 1990's lead to a revival of this kind of quantified techniques.

Daniels and Moore (2002) identify nine techniques – that are briefly described in appendices 3.1, Box 3, page 143 – separating the ones operating on the entire economy or major economic activity fields on a specified geographical unit and those focusing on specific goods, services or process regardless of their location. The first group of techniques includes "total material requirement and output" (TMRO) analyses, the "bulk internal flow" national MFA (or the IFF model), substance flow analyses (SFAs), physical input-output tables (PIOT), ecological footprint analysis (EFA), and environmental utilization of space (EUS) models. The second group of techniques deals with specific goods, services, or processes includes lifecycle assessment (LCA), materials intensity per unit service (MIPS), and the sustainable process index (SPI). One can find a metabolic view point in each of the techniques, in some part comparable to the Ecosystem Health approach. However the vision is here more static and closely linked to the acceptance of the principle "material balance" governed by the first law of thermodynamics (Kneese and al., 1975). This vision makes it important to identify and control physical limits, notably through measure of physical indicators on which long-term sustainability assessment will be possible. These approaches also constitute a useful framework for the comprehension of the linkage between economic demand and activity, and environmental flows.

While extremely coherent with the "material" condition of sustainable development, the MFA framework, in which other techniques can be reformulated (TMRO, SFA, PIOT), is disconnected from the others pillars of SD and only deals with the economic/environment interface. All of these frameworks have to be supported by complementary approaches to assess economic performance and social well-being. In most of the previously described frameworks using the capital or SD pillars based approaches, the disconnection between pillars allows to support such a complementary framework where physical indicators in economic/environment interface are estimated in a unified MFA framework, and economic and social comes from less unified and more participatory procedures. Moreover, ecosystem services and their spatial distribution, which may not be correlated with global substance flows, may not be sufficiently taken into account within these types of approaches.

The main initiatives using MFA seem to focus on chemical substance and material trade, except proposition from Eurostat (Eurostat, 2001) and WRI that analyse a large spectre of material and commodities (Wernick and Irwin, 2005). Daniels (2002) argues that “One major potential of the MFA-BIF information system as sustainability indicator is evident in the research into the human appropriation of the net primary production of plants, MFA-BIF studies are ideally placed to provide detailed biomass flow data for augmenting sustainability research of this genre”. (see appendices 3.2 for an illustration of the Biomass material flows in the IFF MFA-BIF model).

For the agricultural sector and sub-sectors, major MFA initiatives on entire economy flow analysis frameworks integrate agricultural sector mainly through land use (classification of use). These land-based frameworks seem useful as a basis for applying scenarios with quantified evolution of land use in order to evaluate environmental pressure, but they have to be complemented to capture services and value related to the ecosystem quality and their spatial structure. For Agricultural LCA literature, detailed analysis of substance and process analysis (see works of Bentrup for example) exists but one of the most important methodological challenges is related to the mode of spatial aggregation of individual analyses of production process or agricultural system. In LCA, local and regional impacts are often assumed to be equal to the sum of the impacts of each farm, using a simple system of classification (Payraudeau and van der Werf, 2005) with a hypothesis of uniform practices between farmer (Dalsgaard and al., 2003). Here again the focus on impact scheme does not allow to access broad sustainability. Halberg and al. (2005) provide an overview of related techniques on green accounting at farm level.

4.2 Sub-Composite and aggregated SDI approaches

This kind of indices will be treated more in depth within Tasks 2.5 and 2.6 and it will be presented in a future PD. Development of composite indicators is one of the options retained from the early start of SEAMLESS, and the main question is how we will develop such composite indicators. In this section we present the main principles and constraints involved in the use of framework that are able to handle composite and aggregated indicators, illustrating the discussion with some existing frameworks and their comparison.

We will distinguish 1) monetary and 2) physical simple aggregated indicator which involve the transformation of sub-indicators into a single unit from 3) composite indicator which are aggregated indicator measured in different units. Composite indicators are different in the sense that they involve rescaling and/or normalisation in order to make its sub-indicators comparable.

4.2.1 Monetarised indicators: GSR, GPI and ISEW

Indicators and frameworks such as Index of Sustainable Economic Welfare (ISEW), Genuine Progress Index (GPI), Genuine Saving Rate (GSR) and indicators within a green GDP approach, aim to monetarise elements of social and environmental capital which are not accounted for in GDP with an endeavour to introduce inter and intra-generational considerations (Lawn, 2003; Neumayer, 2000; Hamilton, 2000; Hamilton and al., 2003).

This type of indicator was designed in response to certain limits of GDP measurements such as:

- The lack of accounting for income distribution,
- The lack of accounting for non market activities,
- Incorrect accounting for defensive cost,
- No accounting for variation in the value of natural capital.

The idea of the "Genuine Saving Rate" or GSR (World Bank) is that it is important to consider that there exist other forms of capital (human capital and natural capital) and thus derive an improved concept of saving. Saving is interpreted in economy as an income transfer from today to a future period. If the saving is negative, that is if expenses exceed incomes, it will result in debt. The price of these income transfers from future toward present is the interest rate. This interpretation of saving applied to saving of natural capital makes it a measure of sustainability. If the value of genuine saving is negative, then society builds a debt to future generation. Indeed, it is incorrect, in a sustainable development perspective, to consider that genuine saving of a country grows when its natural resources are depleted or degrading to the point where investments in productive capital cannot compensate the losses.
The same is true if knowledge and capacities of the population (human capital) diminishes. GSR however suppose that human capital does not depreciate, and finally takes into account the capacities to save natural resources and the social costs of cleaning up of pollution.

ISEW and GPI are indicators conceptually and methodologically are very close to the GSR. They have been developed, with some variations, in different countries. These indices combine, with different weights, economic factors (also non market activities related to well being), social and environmental factors.

These indicators are based on personal expenses to which are added or deduced gains and losses relative to different consumption. They adopt a monetary approach by evaluating defensive costs and non-defensive costs. ISEW and GPI make adjustments in order to account for the impact of intra generational inequalities. We can formulate the main categories of ISEW as follows:

- Personal expenditure
- Crime and family breakdown
- Household and volunteer work
- Income distribution
- Resource depletion
- Pollution
- Long-term environmental damage
- Changes in leisure time
- Defensive expenditures
- Lifespan of consumer durables and public infrastructure
- Dependence on foreign assets

These frameworks can only imperfectly respond to SEAMLESS project purposes. The analysis that will be conducted within task 2.6 will essentially aim at identifying the different economy/environment interfaces which could respectively (i) fit a monetary equivalent frame and (ii) measure an important part of non-market values (to be determined from existing meta-analysis in literature on transferability of value).

Such frameworks which entail a monetary unit for a set of used sub indicators or variables considered only integrate part of the dimensions of SD. They refer to weak sustainability and usually call for complementary approaches. Although other dimensions are mentioned in initiatives using this type of framework, they are rarely explicit and operational. The main reason is that if other dimensions or non-monetary elements were integrated, they would not fit with the statute of aggregated indicators. Indeed some non-market components of SD are not well adapted to the monetarisation exercise or are for the moment beyond the scope of existing evaluation methods. Such a situation does not fit with the SEAMLESS perspective, at least for 3 among the 4 thematic indicators applied to the agricultural sector (environment, social, institutional). Nevertheless form an theoretical and methodological perspective this approach will be given particular attention within task 2.2.3 concerning the application of the economic pillar at interregional and national scale. A similar conclusion can be applied to the notion of Ecological Footprint detailed below.

4.2.2 A physical indicator aggregated in area unit: the Ecological Footprint (EF)

The ecological footprint (EF) puts environmental sustainability in a spatial perspective. It was first defined as "the **area** of ecologically productive land (and water) in various classes that would be required on a continuous basis to provide all the energy/ material resources consumed, and to absorb all the wastes discharged by a population with prevailing technology, wherever on earth the land and water is located" (Wackernagel and Rees, 1996). EF is the main aggregated indicator using a physical equivalent for all variables considered (see also the Living Planet Index [LPI] published every two-years by WWF). The EF proposes an indirect measure, expressed in physical terms, of the society-environment relation, relying on the carrying capacity concept.

The footprint can be compared with nature's ability to renew the human consumption of resources. It groups and calculates material and energy requirements of nations or regions for a limited number of consumption functions, converts these metabolic flows into the ecologically productive land area required to produce the resources used in these activities, and compares the required areas to available regional, national, and global ecologically productive areas. Existing studies have typically been restricted to the ecological resource output potential of terrestrial areas (Daniels and Moore, 2002).

This index accounts essentially for some environmental aspects through resource consumption and neglects numerous variations in the values and services produced by ecosystems or by biodiversity that can be associated with different modes of consumption and with different modes of territorial managing. It does not account for any social or institutional aspect, however without pretending to do so. Its main advantages are:

- Its capacity to encompass the whole production and consumption chain through its consumed energy entry, thus providing a coherent frame to measure impacts induced by the consumption of a country or a community on the rest of the world.
- Relevance in comparing environmental advantage between competing productive policies.
- It can be used at different scales.

However, EF should be used with caution (van den Bergh and Verbruggen, 1999; Nijkamp and al., 2004). Three reasons can be mentioned:

a. EF is incomplete.

In dealing with consumer goods[1], land equivalents account for:

- the energy mobilised in the fabric of consumer goods (indirectly through CO2 absorbing forest land mobilised by fossil-fuel equivalent of this energy), from basic materials and agricultural products.
- the energy mobilised in extracting materials and in agriculture.
- the land used for agriculture.
- the land used for growing wood material.

So availability and depletion of non-renewable resources is not addressed, and this distorts trade-offs. Then, ecosystem services are only present through CO2 absorption related to energy use: other absorption of pollution is absent. This is why agricultural practices are all considered sustainable: so intensive fertiliser use can ameliorate the EF because it mobilises less agricultural land for a given production. This however means that negative effects on land or water systems involved in absorbing these fertilisers are not accounted for.

b. The EF aggregation scheme is questionable.

All the land mobilised for energy use, agriculture or urbanisation is added on an equal weighting basis. Improving this approach would mean to start using some kind of equivalence theories such as monetary evaluation of relative land value, which is what the principle of land equivalent and physical unit in general is trying to escape from. Then, the calculation relies on "one land-one use" basis to avoid double counting: this does not relate the variations in how land plays different roles at the same time, and therefore with the issue of multifunctionality.

Another restriction concerns the choice of the area units analysed. National boundaries, for instance, do not have a clear environmental meaning. For instance, comparing (i) a large, scarcely populated country with a high level of consumption and an ecological surplus with (ii) a small, densely populated country with, say, an equivalent an equal level of consumption but a significant ecological deficit[2], does not immediately offer relevant information about which country is on the right track towards sustainability. In addition, at any level apart from the global, the EF should be seen as the net input of virtual land from outside the analysed system. The EF is essentially more a meaningful ecological dependency indicator for a given area, which is scale dependent. The geographical scale inherent in the EF calculation is, therefore, the Achille's heel of the methodology (from Nijkamp and al., 2004).

c. The interpretations of Ecological Footprint are not straightforward.

First the shortcomings described above imply that EF may have to be used partially or completed following particular goals. Moreover the increase in EF caused by transport seems to plead for self-reliance more than exchanges among entities. This has to be considered against other advantages, that involve for instance socio-cultural issues exceeding the scope of the EF. However, such socio-cultural issues may indirectly benefit in monitoring EF through increased co-operation among relevant entities, since we are not in closed economies

[1] Wackernagel and Rees (1996) divide consumption in 5 main categories: food, services, transportation, consumer goods and housing.

[2] Ecological deficit is an indicator of dependence on out-of-boundary ecosystems. It gives an idea of the extent to which a country, region or city is dependent on extra-territorial productive capacity through trade or appropriated natural flows.

and physical or monetary exchanges occur. An unbalanced EF between cities and rural zones in a country may reveal societal compromises (when general interest and redistribution is ensured by government). Conversely if general interest is not ensured, unbalanced EF can reveal injustice in appropriation of natural resources and services. So the EF can be a policy relevant tool because it points at balances that have to be addressed (but through cautious interpretation), allowing to compare certain environmental advantages of competing productive policies.

The use of a framework adapted from the ecological footprint in an agri-environmental setting would call for important theoretical and methodological developments. Its present use can only be justified as a partial contribution within thematic environmental indicators. The EF indeed represents a powerful prospective tool to account for energy consumption associated to different options of agricultural policies (consumption induced for production of inputs, consumption induced in transporting finished goods) in Europe, but also for consequences to the rest of the world (induced reorganization of agricultural productions and of natural resource use in other countries). In this sense, it is a tool which is susceptible, from an environmental point of view, to justify the subsidizing of short distribution networks as well as the promotion and maintenance of a diversified domestic production.

4.2.3 Two composite indicators: IUCN and 2005ESI initiatives

4.2.3.1 A participatory composite indicator by IUCN (International Union for the Conservation of Nature and Natural Resources)

Definition: two-subsystems (human and ecosystem) and 2x5 compartments, leading to indicators assessment

IUCN has developed a comprehensive tool for assessing sustainability of human related systems, at various scales and with various scopes (IUCN, 2001).

This tool comprises a plan for articulating successive stages of the sustainability assessment, with guidance on participative involvment when relevant. The first steps of the method are designed to make explicit the scope and purpose of the particular initiative, its assumptions and how these purposes may affect the participative elaboration of indicators in the next steps. IUCN (2001) presents a comprehensive tool, but partial use of the method is possible depending of the purpose of the use. For instance one purpose can be to evaluate the evolution of a situation after a previous assessment

In general, the sustainability assessment is not designed to replace project planning or monitoring, but to structure the material and data needed for informed decisions, because the scope, spatial area and time span of the assessment are often larger than that assessment which is necessary for project planning.

This framework divide sustainability into **ten compartments**, five for the human system studied and five for the ecosystem forming its environment:

- health & population,
- wealth (national economy & household economy),
- knowledge & culture,
- community (peace & order and freedom & governance),

- equity (gender equity and household & ethnic equity),
- land (quality & diversity),
- water (inland waters & sea),
- air (global & local atmosphere),
- species & populations diversity,
- resource use (energy & materials and resource sectors).

These ten compartments are supposed to cover most of the human related sustainability issues that can be encountered. A composite indicator for each contextually relevant dimension is to be derived through local participative process, ensuring concerned people design their own vision of sustainability, provided the number of dimensions between people and ecosystem are equal. This approach aims to ensures equal treatment of people and ecosystem well being.

The composite indicators representing each dimension are then aggregated on an equal weighting basis, first into a human well-being index (HWI) using the five human-related indices and a ecosystem well-being index (EWI) representing the five ecosystem compartments. This translates IUCN's view that the two subsystems are not substitutable. Under this condition, the HWI and EWI can then be aggregated or put into a ratio.

The interactions between these two subsystems are considered within the subsystem where the impacts are felt: human stresses (pollution...) and benefits (conservation) on the ecosystem are recorded under 'ecosystem' and conversely.

Indicators are judged following the four criteria: measurability, representativity, reliability, feasibility. Indicators measuring directly the state of an element are considered more reliable than indicators of pressure on this element or indicators of societal response to perceived problems derived from the element. State indicators are thus privileged in the process.

Comments on the assumptions supporting IUCN's initiative.

First, equal treatment of people and ecosystem places the framework within an environment-society interface. The economy is considered explicitly within the people subsystem, but weighting one tenth in sustainability issues since it is one of the 10 compartments; for the rest it only has an indirect role through implicit participation in other issues and relations. So this framework may not be sufficient to relate economic functioning if it is considered essential to SD. On the other hand, its relative emphasis on social concerns balances many other frameworks and can help show the importance of the relation between 'social' condition and environmental degradation or concern.

The separated assessment of human system and ecosystem shows IUCN's non-compensatory approach relying on strong sustainability (which is uncommon in composite indicator initiatives), however the usual (non)substitutability pivot between natural capital and technology is not emphasised because economy has little place.

Second, the manner in which the relations between people and environment are accounted for is not very clear (as is often the case it is left to indicator fabrication to highlight these links). For instance, human economic activity produces pollution, which has an impact on environment; further, degraded environment has an impact on human health. Since relations are considered within the subsystem where impacts are felt, both phenomena are recorded separately, whereas in a PSR-type chain the causality relation is put forward from the economic activity to the health impact. Even though such a causality is a simplification, the correlation should be presented. Assessing "where the impact is felt" to record phenomena is implicitly assessing for pressure-state relations, using state indicators to reliably assess a causing phenomena and an effect phenomena. This may be more reliable, but hardly more explicit.

More over, one way of knowing if a response indicator is reliable is to measure it and face it (with the prudence commanded by uncertain interrelations) to the evolution of the state of the targeted phenomena. As far as policy relevance is concerned, state indicators give a more reliable picture of the situation, and hence enable to derive new solutions from new insights. But response indicators combined with state indicators tell whether policies are implemented and if they are sound and sufficient. IUCN's preference for state indicators is however coherent with what the organization expects from a sustainability assessment of policy: to provide a solid and balanced information and rationale to inform decision making.

An essential feature of this method is the idea that developing a vision of sustainability is participative and context-specific, so that priorities are derived by those who are concerned and respect local feasibility: this reflexive procedure and responsibility appropriation is considered as important as the indicators actually produced.

The relative importance given to societal concerns by the people-ecosystem framework of IUCN is particularly consistent with the fact that the rest of the assessment is locally involved and that a thorough participative guide is provided. Indeed, social and quality of life concerns are often context-specific and the demand for such indicators is expressed in numerous surveys.

4.2.3.2 A composite indicator dealing with protection and management of environment: the 2005 Environmental Sustainability Index (2005ESI)

The 2005 Environmental Sustainability Index (2005ESI) lead by Yale University is a composite indicator dealing with protection and management of environmental resources and stresses (Esty *and al.*, 2005).

While environmental sustainability refers to the long term maintenance of valued environmental resources in an evolving human context, the 2005ESI's emphasis is policy-oriented and focuses on a shorter term period: it provides a gauge of a society's natural resource endowments and environmental history, pollution stocks and flows, and resource extraction rates as well as institutional mechanisms and abilities to change future pollution and resource use trajectories.

It only deals with economic and social issues insofar as they relate to their environmental sustainability objective, through the following logic. The 2005ESI framework is divided into **five core components** (or thematic categories):

- Environmental Systems (are they healthy, deteriorating or ameliorating?)
- Reducing Environmental Stresses
- Reducing Human Vulnerability (food, health, disasters)
- Social and Institutional capacity (institutions and underlying patterns of skills, attitudes and networks that foster effective responses)
- Global Stewardship (international cooperation and reducing negative trans-boundary impacts)

These five core components greatly overlap with the D-P-S-I-R model, centered on environmental states. Pressures and social response as well as response capacity are important to bring environmental sustainability into the classical 4 steps process of diagnosis, target setting, implementation and evaluation in project management. .

Each of the previous five components encompasses between three and six composite indicators of environmental sustainability. This leads to 21 indicators that are aggregated to create the 2005ESI, while components are thematic clusters that don't intervene directly in actual aggregation. The 21 indicators are composite, meaning they are aggregated from a variable number of basic indicators (out of a total of 76 fixed indicators; see appendices 2.1.2.4 page 114) chosen to represent the scope of the composite indicator selected.

The hierarchical construction of 2005ESI from basic indicators includes the definition of indicators, and a fixed aggregation scheme through statistical normalization and equal weighting. The reason for this is that 2005ESI aims at comparing performance between countries, for policy making purposes. However, the promoters of 2005ESI provide evidence through sensitivity analysis that the weighting scheme is robust: a survey of expert weighting not only doesn't change weights much, but the result of 2005ESI is fairly insensible to this change. A similar conclusion comes from aggregating the five components instead of the 21 building blocks esty (Esty *and al.*, 2005).

Some interesting conclusions are also derived in the initiative, concerning relationships between 2005ESI and economic development or the central role of governance. For instance, it appears that the highest bi-variate correlation between 2005ESI and basic indicators involve governance-related elements: civil and political liberties, survey data on environmental governance, World Bank gauges of governmental effectiveness etc. Further references to support this issue can be found in the 2005ESI website [http://www.yale.edu/esi/], as well as critiques and responses given (appendix H in Esty *and al.*, 2005).

4.2.4 Comparing sustainability indicators initiatives

4.2.4.1 EF and 2005ESI

The Ecological Footprint can be compared with the 2005ESI because their goals are similar.

The EF is a physical one-unit aggregated indicator, where the interpretation of environment contains no social building elements and relies on calculation of economic mobilisation of resources. It focuses on the environmental-economic interface. Although this could apparently limit its scope, the answer is more complex. The ability of the EF (i) to account for environmental use inside and outside the considered system, and (ii) to compare certain impacts of different production/consumption options and patterns, can subsequently reveal (un)balances and guide interpretation in terms of equity, thus enlarging its relevance within the debate about sustainable development.

The 2005ESI integrates social concerns in the indicators it aggregates, while focusing on social organisation adapted to answering environmental challenge. It focuses on the environment-social interface (though social concerns such as equity are not accounted for). It is also more complete in the environmental domains it encompasses. Its interpretation is easier in the sense that differences in scores are more directly linked to environmental issues: indeed 2005ESI indicators were chosen because they are related to policy issues dealing with environmental sustainability. On the other hand, this higher completness implies it is more difficult to use the 2005ESI score for comparing particular issues (for instance agricultural policies).

However, the 2005ESI and the EF are complementary in comparing respectively environmental management and production/consumption patterns between different countries.

4.2.4.2 2005ESI and IUCN initiatives

The aim of creating comparable evaluations in time and space explain the fixed 2005ESI scheme. This is an important difference with IUCN's initiative, which is locally adaptable to local vision of sustainability. This has consequences on how the subjective choice concerning the contribution of indicators to SD is made. For 2005ESI, the 76 indicators are measured and then normalized with statistical methods. Thus the normalized indicators are more related with the performance of a studied country relatively to others, than with a subjective idea of how the indicator contributes to sustainability (sustainability relatively to the particular block it is assigned among the 21). Conversely, indicators representing one of the ten domains of sustainability derived by IUCN, are measured and a grade (on a scale from 1 to 5) is attributed to this measure. This is followed by an assessment of how it satisfies sustainability objectives derived through local participation. In both initiatives, the building blocks (10 for IUCN, 21 for 2005ESI) are aggregated with equal weighting.

The two initiatives also differ in scope since 2005ESI is about environmental sustainability whereas IUCN aims at assessing sustainability in a broader sense, but through a binary people-ecosystem perspective.

However both initiatives end up emphasising very similar elements.

- In the environmental blocks considered. The five ecosystem dimensions of IUCN and the five indicators for environmental systems in 2005ESI, are quite similar, except that 2005ESI does not consider non renewable resource availability which it shares in common with the Ecological Footprint,
- ESI articulates the D-P-S-I-R model in a way that emphasises certain functions such as "reducing human vulnerability", "ensuring social and institutional capacity" of response to environmental challenges, or participating in global stewardship. These functions fit well in a systems-approach suggested Bossel (1999), where properties such as security, adaptability, or coexistence are in the framework. This way of combining PSR causal and policy oriented procedures with system properties emphasises the role of social organisations in dealing with environmental sustainability. The 21 indicators of 2005ESI (logically) fit in the ten dimensions of IUCN, and among the 76 basic indicators used in 2005ESI, many fall into "community", "health & population", "knowledge" categories as derived by IUCN. There are 10 social and institutional indicators for 11 environmental indicators. Still, culture and equity are two dimensions that relatively absent in 2005ESI, as also is the wealth dimension, but this last is not a strong point of IUCN either.

The point is that while IUCN assesses the state of people's well-being and ecosystem's well-being as a model for sustainability, it implicitly highlights relations between both (also through pressure relations), whereas the 2005ESI initiative explicitly relies on adequate social context to foster responses. As a result, 2005ESI ends up covering a large part of IUCN dimensions, even though because it is dealing with social concerns more indirectly some issues such as equity and culture are rather absent.

4.2.4.3 IUCN and system-based frameworks

The "ten compartment" framework of IUCN is seen to be fairly universal in covering sustainability concerns and in that sense it shows similarities with the Bossel 1999 system-based framework. However the IUCN universal compartments are environmental blocks for the ecosystem and societal issues for the people subsystem, instead of sustainability proprieties applied to the three dimensions of SD seen as subsystems. This is the part of the framework that creates emphasis on SD dimensions and global balance. In Bossel's system-based method, which properties among the basic orientors are contextually relevant, which indicators should represent these properties and how indicators contribute to them, is thought to be context-specific and derived through participative process. The same principle is relevant for the IUCN approach, the decision of which compartments among the ten should be used (provided equal treatment of both subsystems is ensured), which indicators should represent them and how these indicators contribute to local sustainability is up to the participatory process.

4.3 Transversal ideas used in SDI framework

4.3.1 Carrying Capacity and related concepts (Eco-efficiency, Limit to growth and Steady State Economy)

Carrying capacity can be defined as the maximal population of a living species in an ecosystem can withstand. This notion is context dependent and is only valuable for a fixed amount of resources. If the population in an ecosystem is living under these conditions their the functions of the ecosystem are preserved, and the population can live and reproduce. This implies necessary natural resources, for consumption and waste absorption are available (UN, 1996).

Central to carrying capacity is the notion of maximal population density, which is the population at which pressure on the environment leads to ecosystems breakdown, or to resource insufficiency. Considering humans living on earth, this point is largely unknown, because the human system and natural system are to complex and interrelated.

The notion of maximum population density is different than the population at which natural sink capacities are surpassed, leading to a polluted environment, but where population can still grow. This difference implies there is a level of pollution acceptable for society, that has to be determined through political process.

Carrying capacity can be interpreted as a sustainability concept that links human activity (through material and services consumption), with environment, but indirectly through population: this makes this intended limit a variable notion, depending on consumption of the population, which itself changes with technology and habits.

Besides, carrying capacity doesn't decide if it is only the functions of the environment that are vital (directly or indirectly) if the human population is to be preserved, and if so if they should be preserved at the expense of others: it carries no normative presuppositions.

This is why the concept is interpreted diversely in different conceptual frameworks. For those (eco-space..) who consider economic growth as the leading perspective, technology is seen as a main factor increasing carrying capacity since it enables greater activity for a given load on environment. If the environment mainly is seen as a resources for activity, natural systems are considered substitutable by technology, and environment degradation is acceptable if compensated by services available through technology, because carrying capacity is maintained (weak sustainability). Since the balance between the numerous interrelated ecosystems on earth is unknown, this usually goes with counting on technology to solve possible provoked disruptions.

For others (steady state economy, limits to growth, ecological footprint, ecosystem health..) carrying capacity is the constant limit relative to ecosystems breakdown, implying that ecosystems preservation is a priority and that environment is not substitutable. This argumentation can stem from a different rationales, for instance where it is considered that humans have no priority on other living beings, and/or where other use and non-use values of the environment for humans should not be set aside for purely economical concerns, and/or having a precautionary attitude towards uncertainty where technological substitution is concerned.

The eco-efficiency concept (UN, 1996) is intermediate to these approaches. By emphasizing sink and waste limits, it implies that renewable resources (clean water, clean air..) are not substitutable; in the same time, the concept is about achieving economic growth within these limits, even though this possibility is contested.

Note that carrying capacity was refined with the notion of ecospace (EUS) introduced by Opschoor, extending it by using directly human economic activity as a measure of critical loads (see The Rosendal workshop UN, 1996). Here, it is transparent that the efficiency of an activity's consumption of natural assets enables to lower the pressure on environment. Being more flexible than the eco-efficiency on environmental preservation, they both emphasize reduced energy and material inputs and polluting outputs through technological innovation, even though eco-efficiency is used by some to promote a more profound cultural change in habits, because technology has its limits (concerning renewable resources, topsoil for instance).

This emphasis on technology's role is translated by the economist's notion of decoupling economic growth from material throughputs, where processes tend to dematerialize in time with technological progress: although the importance of such trends are contested in the past (see Hammond in OECD, 2000), it forms an objective being put in application in the OECD decoupling set of indicators initiative (see OECD, 2003) .

4.3.2 Ecosystem health

Rationale and definition

Ecosystem health (EH) is close to systems approaches for sustainability assessment. It was initially proposed by environmentalists as a concept for managing environmental resources (Becker, 1997). The general approach of this initiative is to extend the idea of health to the ecosystem level. It puts ecosystem health at a similar level as human health, and stresses the importance to understand the links between ecosystem and social systems when both are considered as organisms (USDA, 2002). The concept of health, which was developed for the individual (e.g. human, animal and plant health), is here extended to the population (e.g. herd health), as well as to the ecosystem (Rapport, 1989). "The language of health is public, non-sectarian and bridges scientific specialities and cultures. Health thus provides a model for science, practice, and public discourse on agro-ecosystem evaluation" (Waltner-Toews, 1996).

Proponents of this concept (Rapport, 1992; Costanza, 1991) stress its holistic perspective, based on a positive vision instead of focussing on single degradation symptoms. This entails an integrated vision of environment, and is also aims to be consistent with Thompson's view of "functional integrity" (Thompson, 1997). Functional integrity prioritises a system approach including human activities and privileges the future state of a system rather than the present state of the resources that are being exploited. In agreement with Bawden (1997) (EH invites us to adopt another viewpoint and move beyond the strictly anthropocentric or technological vision that generally prevails in agronomic sciences, while avoiding to become trapped in a solely ecocentric analysis, which would privilege a strict naturalist approach only (Hubert, 2002). This shift in viewpoint would enable to arrange the values - that give strength to facts and can provide guidance for defining targets - into their societal context (Lackey, 2001).

EH may be **defined** as the "*capacity for maintaining biological and social organisation on the one hand and the ability to achieve reasonable and sustainable human goals on the other*" (Nielsen, 1999; cited by Rapport, 2000)). A healthy ecosystem is one that is free from distress and degradation, maintains its organisation and autonomy over time, and is resilient to stress (Rapport and al., 1998) while capable of remaining economically viable and able to sustain human communities (Rapport, 1995). Ecosystem health can be assessed by indicators that reflect properties of vigour (productivity), organisation, and resilience mageau (Mageau and al., 1995; Costanza and al., 1998a, 1998b). Drawing on previous theoretical and empirical work, Gallopin (1995) has discussed key differences between an ecosystem in conventional terms and agro-ecosystems and proposed six attributes of agro-ecosystems : availability of resources, adaptability, robustness, capacity of response (including proactive), self-reliance and empowerment. The approach has been applied to various ecosystems: aquatic (Scrimgeour and Wicklum, 1996; Xu and al., 2005), semi-arid (Muñoz-Erickson and al., 2004) but new domains of application emerge, namely in agriculture (Wilcox, 2001). Agro-ecosystems health should in some sense be related to its ability to adapt to variations in its changing socio-economic and ecological context (Van Bruchen, 1997).

The definition of system goals gives room to collaborative processes:

- Scientific collaborations among disciplines: ecosystem science, conservation biology, landscape ecology to define reference points for ecosystems (Steedman, 1994), social sciences and economic methods to contribute to inform desirable states for healthy human communities. Methodologies for EH assessment would be supported by emerging fields such as social ecology (Hill, 2005), human ecology and environmental sociology (Peine and al., 1999) .
- Collaborations with stakeholders, namely based on consensus building methods (Innes and Booher, 1999) and/or collaborative learning (Daniels and Walker, 2001; Kenney, 2000) seeking to more effectively link the ecological and social aspects of ecosystem management with a participatory approach. This participation is possible during the evaluation stage (Steedman, 1994).

Assessing ecosystem health

Measures of EH include bio-physical, social, economic, and human health indicators (Rapport and al., 1985).

However, practical ways suggested for EH assessment show some discrepancies with the above mentioned principles. Assessment of EH as a socio-ecological entity would require analysis of :

- mechanisms by which human activity degrades ecosystems
- consequences of ecosystem degradation for the capacity of ecosystems to supply "ecological services"
- impacts of the loss of nature's services on human health, economic opportunities, community well-being… (references in Rapport, 2000).

EH is an integrative notion and an idea, describing a complex set of ecological realities, rather than a condition that can be measured directly: "EH does not embody non-ambiguous rules for its measurement or valuation. These must be provided by the practitioner, preferably in the form of scientifically based decision rules and benchmarks set in a well-documented social and cultural context" (Steedman, 1994). It can therefore provide guidelines and be considered as a programme with reference points. Such is the paradoxical nature of ecological health it is at once descriptive and prescriptive, objective and normative (Callicot, 1992).

In addition, many indicators of ecosystem pathology are manifest in an "ecosystem distress syndrome" (EDS) (Rapport *and al.*, 1985). Conversely, both the economic and social dimensions are rather vague when EH evaluation is at stake. Michalos (1997) suggested ways to combine such dimensions to measure sustainable well-being. He argues that if we wish to quantify human well-being, a comprehensive system of indicators should include not only economic and social indicators but also indicators of environmental degradation and resource conservation. He also suggests that different dimensions of sustainability will necessitate the use of different indicators and methods. The energy example is discussed with attention paid to the costs of energy exploitation, often not accounted for in traditional cost-benefit analysis. A "cost-benefit dominance" approach would enable to alleviate this problem. In this procedure, a group of social-economic-environmental phenomena that are generally agreed to be positive or negative indicators of well-being are identified and monitored over time.

The EH approach is ecologically centred, in its scientific sense. Nature is not exclusively at the service of people. Productivity is not the primary objective. What is being sought is rather how to deal with nature's functioning, how to preserve the integrity of the biological processes and geochemical processes on which these functions are based. The notion of ecosystem enables ecologists to represent the world and the way it functions, its cycles, balances and dynamics. Yet, ecosystem has no definite spatial dimension (Hubert, 2002). For instance, what are the (both spatial and temporal) boundaries and the hierarchical level of the "patient" ecosystem? Who defines the "illness" and how is it diagnosed? What role science and scientists play in defining EH? How effective is ecosystem ecology in addressing environmental problems? To answer such questions, attention must be paid to specific domains of application.

Operationalizing ecosystem health

The notion of EH can be considered as a tool to implement the idea of sustainability into complex bioregional scales.

A Holistic Ecosystem Health Indicator (HEHI) was proposed in Costa Rica as a framework for the development and structure of indicators based on the EH notion (Muñoz-Erickson *and al.*, 2004). It incorporates specific management objectives of the area involved, while also useful for making comparisons leading to regional policy-making (Aguilar, 1999).

The HEHI follows a hierarchical structure starting with three main branches: ecological, social and interactive. The last branch includes measures and related to land use and management decisions that characterize the interactions between the human communities and the ecosystem.

Each branch is sub-divided into categories or criteria, which further operationalise the meaning of each branch, yet these sub-divisions are not a direct measures themselves. Categories reflect particular attributes of the management objectives for the studied system, based on the ecological and social characteristics of the area and management goals of the stakeholders involved. The categories are comprised of indicators that serve as the measure for the performance of each category. For example, soil quality is a category within the ecological branch and it can be measured using indicators such as microbial biomass, water infiltration and compaction.

Each indicator is given a target or benchmark, based on references available in scientific literature and specific objectives defined by management objectives or policy (*e.g.*: a water quality indicator can have a target defined by legal limits specified by the administrative authority in charge, while a target for a productivity indicator may be defined by a combination of the capacity of the system and objectives set by stakeholders). To prioritize the importance of each category and indicator, weighted scores are assigned to each based on its relative importance to the heath of the system and to stakeholders goals.

Categories are ranked and assigned points from a total of 1000 as "high", "middle" and "low" measures of EH.

- high measures refer to key resources and interactions; they reflect management objectives of the area,
- middle measures critical factors in the function and persistence of the system, but are not central goals,
- low addresses still unclear interactions between indicators and EH or not well developed methods.

Box 1: Applications of EH Indicators for the sustainability of Protected Zones in Costa Rica (Aguilar, 1999).

Some difficulties have been identified in this site-specific process: what are the appropriate variables to be measured for a different system? What are the appropriate time scales to track management progress, and by what benchmarks does one evaluate success or failure of management? What would be a relevant number of indicators? If too few are monitored, important elements of the system may be overlooked; if too many are monitored, then data acquisition may be cumbersome and expensive.

Prior to establishing benchmarks of EH it is crucial to establish a conceptual understanding of (i) the system dynamics and structure (using existing scientific literature), (ii) the essential systems components (identifying site-specific parameters) is necessary (Bossel, 2002). This lead Muñoz-Erickson *and al.* (2004) to develop a methodology based on participatory research to assist the process of developing appropriate indicators for the HEHI framework.

To demonstrate the utility of this approach on a site-specific basis, the authors have been working with a northern Arizona collaborative rangelands management group (Muñoz-Erickson and Aguilar-Gonzalez, 2003).

Five steps were identified in this area:

1/ The definition of EH, with a three-part holistic goal (goals for : quality of life, forms of production, future landscapes and resource base) and organisation of indicators,

2/ The development of a conceptual model (linking EH with processes and conservation /production objectives; driving factors influencing system characteristics),

3/ The input of local knowledge (focus group and stakeholders interviews),

4/ The identification of a "candidate set of indicators" (with expert consultation: natural/social scientists and resource managers), 5/ The development of a HEHI structure: finalised indicators and ranking, testing of indicators (ecological, social and interactive).

Based on scientific literature, expert opinion, and interviews with stakeholders, 14 key indicators have been selected: soil quality, vegetation, watershed health, primary productivity, erosion, wildlife, demographics, economic viability, access to services, community strength, land distribution, land use, public awareness and perspectives, social capital, and implementation of regulations. Data-collection protocols were developed for each indicator and applied in 2003. Based on ecological data and field experience in this area (Muñoz-Erickson *and al.*, 2004) created hypothetical response curves for nine ecological variables along a vegetation gradient, ranging from pure grassland to closed-canopy forest. For each of the hypotheses, a rationale explains the vegetation response, based on available scientific information. This leads to a ranking of indicators of ecological change, based on ecological response variables. This framework would allow managers and stakeholders to define and prioritize adaptive management strategies, facilitate communication among stakeholders, and assess progress towards their goals.

Schaeffer and al. (2000) explore an approach to ecosystem analysis which identifies and quantifies factors which define the condition or state of an ecosystem in terms of health criteria. They relate ecosystem health to human/non human animal health and explore the difficulties of defining ecosystem health and suggest criteria which provide a functional definition of state and condition. They suggest that, as has been found in human/non human animal health studies, disease states can be recognised before disease is of clinical magnitude. In the same mode example disease states for ecosystems are defined and discussed, together with test systems for their early detection.

Concerning lake ecosystem health assessment, an EH index methodology (EIHM) was developed and applied in thirty Sicilian lakes (Xu *and al.*, 2005). This methodology enables comparisons among situations and quantitative assessment of the actual health status of lake ecosystems, based on a numerical scale from 0 to 100.

Another relevant domain is the measurement of EH at landscape scale (Patil and al., 2001). The authors describe the challenges of reporting on changes in ecosystem health at landscape scales, and review the statistical and mathematical techniques that allow the derivation of landscape health assessments from a variety of data consisting of remote sensing imagery, demographic and socioeconomic censuses, natural resource surveys, long-term ecological research, and other geospatial information that is site specific. They draw upon seven innovative and integrative concepts and tools that together will provide the next generation of ecosystem health assessments at regional scales. They show how the integration of recent advances in quantitative techniques and tools will facilitate the evaluation of ecosystem health and its measurement at a variety of landscape scales. The challenge is to characterize, evaluate, and validate linkages between socioeconomic drivers, biogeochemical indicators, measures of multiple-scale landscape patterns, and quality of human life indicators. The initial applications of these quantitative techniques and tools have been done for regions in the eastern United States.

Interest and limits of EH

Many points of controversy appear about the concept of EH (Lackey, 2001). Becker, (1997) suggests "ecosystem relevance" as a specific condition for the selection of Sustainability Indicators, in addition to 3 additional conditions: scientific quality, data management, and sustainability paradigm. Ecosystem **relevance** cover several criteria, which can be grouped into (i) desirable properties to determine the sustainability of ecosystems and (ii) indicators properties based on systems theory.

However, indicator properties cannot always be proved in practice (e.g. large scale and long-term effects, such as global warming, are beyond the scope of experimental evidence from full system cycles in systems theory). Thus a balance must be found between accuracy and pragmatic decision making. The suggested conditions and criteria can be used to evaluate indicators and guide their selection according to the purpose of users, applying a matrix approach. This is consistent with Bernstein (1992) position, arguing that "the ideal trend indicator should be both ecologically realistic and meaningful and managerially useful".

As an integrative notion, EH is not meant to rely solely on scientific proof in a hypothetico-deductive sense and it does not pretend to give predictive descriptions of causal mechanisms of socio-ecological systems, but rather to provide case by case evaluation in their real world setting (Wilcox, 2001). How does EH relate with other frameworks and approaches?

The EH approach shares some common features with *DPSIR approaches*, namely in the identification of driving forces and pressures. This is perhaps not very strange as they are to a large extent driven by a natural scientific or almost chemical approach to nature, where everything is about balances in processes and time whereas irreversible changes seem forgotten (See Olsson *and al.*, 2004). Although an "ideal" EH conceptual model would identify causal relationships between each stressor and ecosystem level response, the complexity of multiple, simultaneous processes precludes the possibility of creating such a model. In the case of semi-arid rangelands, many of the current ecological models describe future conditions in terms of achieving some single, desirable equilibrium through adjusting livestock numbers with an optimum "carrying capacity" (Walker, 1993).

As an alternative, the *state-and-transition* model offers a more realistic interpretation of these ecosystems, taking into account the complex array of factors such as spatial variations and dynamics, event-driven change, lag effects and thresholds (Scheffer and al., 2001), resilience and irreversibility, changes and variations in productivity, and the notion of multiple meta-stable states coupled with multiple trajectories of change (Westoby and al., 1989; Laycock Laycock, 1991). Together with other approaches such as "Natural Resources Management", EH in this latter interpretation invites to another vision of environment, not considered as a set of compartments. This does not follow the "mainstream" of other representations of environment.

Another challenge consists in relating ecosystems with *social dimensions*,. "Understanding the loss, creation, and maintenance of resilience through the process of co-discovery (by scientists, policy-makers, practitioners, stakeholders, and citizens) is at the heart of sustainability" (Gunderson and Holling, 2002). However, the implementation of such principles into practical contexts has not been evidenced. Hill (2005) also proposed social ecology as a framework for broadening, deepening, redesigning and improving our conceptions of sustainability and social capital. Such conceptions need to be understood in the context of our dominant cultural and institutional structures and processes, and in terms of their negentropic (capital-building, progressive) co-evolutionary development. Likewise, Hodge (1997) aimed at identifying an existing conceptual framework that could serve as a model for the human-ecosystem interface. This model could be used by decision makers and it should satisfy 5 criteria:

(1) the components and their relations are adequately defined,

(2) the value base underlying the concept of sustainability is reflected

(3) the model includes a systematic approach to describing human-ecosystem interactions in which both the individual components as well as the whole system can be understood,

(4) the physical system and its relation to the human decision making process are accurately described,

(5) the model should easily lead to an organisational framework for assessing progress toward and reporting on sustainability.

Sustainability and EH are related concepts. One major difference between them relies in the fact that many approaches of sustainability emphasised the economic dimension, whereas EH overlooks economy while giving privilege to environmental and human aspects… Yet, sustainability is often applied to specific domains (i.e. sustainable agriculture as one sector of a landscape type), while EH can assist in measuring endpoints at regional scales, as the concept is biophysically and bioregionally grounded. This could also be a "breakpoint" between ecosystem health and integrity: according to Lackey (2001), EH can be considered as the preferred state of ecosystems modified by human activities, whereas ecological integrity corresponds to an unimpaired condition in which ecosystems show little or no influence from human actions. Ecosystems with a high degree of integrity are natural, pristine, and can be labelled as the base line or benchmark condition. Natural ecosystems would continue to function in essentially the same way if humans were removed. However, Wicklum and Davies (1995) suggest that neither health nor integrity are inherent properties of ecosystems. The *policy relevance* of EH is also debated. Some authors are sceptical about EH as a useful framework for land management policy (Freemuth, 1999), taking into account the fact that policies are sometimes determined at other or higher levels than the regional. Other issues that are debatable in relation to EH approaches is how an appropriate timescale by which to track progress can be defined, and by which benchmarks does one evaluate success or failure of management? Restrictions in scales may also lead managers to adopt a uniform set of indicators across broad regions (Noon, 2003). Regardless of these academic debates, integration of EH could contribute to frame important policy issues (i.e. sustainability of agriculture, scarcity of water for domestic and agricultural use, ecological consequences of introduces species…). Ecological policy issues are not mere intellectual concerns, but matters that affect people's daily lives (Shrader-Frechette, 1997).

In this sense, public involvement should be at the essence of using normative concepts such as EH because of their requirement for inherent value judgments (Lackey, 2001).

4.3.3 Biodiversity issues

As for sustainable development, and natural resources, biodiversity indicators are subject to many initiatives in the world. Biodiversity conservation is a central issue of SD and was put forward as an important principle of sustainable development by CBD. Numerous SDIF thus integrate a series of indicators to account for entropic pressure on biodiversity, for its conservation state and for efforts concerning biodiversity management. Scientific production on this type or indicators is very important and expanding. Different and competing conceptions exist of what an biodiversity indicator should measure and how. By and large, we can distinguish descriptors elaborated from information on spatial organization of land use at different scales, and bio-ecological descriptor of ecosystem elaborated from information on species and habitats (inventories). From the role of agricultural spaces point of view, two specific entries are essential:

- The role of agricultural practices on domestic and surrounding cultivated land biodiversity. From this point of view, examples are relying on the impact of agricultural practices at the farm scale and the AEI framework can be adapted for this use. Identification of biodiversity enhanced experts meetings (OECD, 2001; on agri-biodiversity indicators), and included their coverage and compatibility with the various levels of diversity (genetic, species and ecosystem).
- The role of maintaining agricultural space in peri-urban and rural areas. In this case,

land cover data and analysis of their composition and organization can permit to create landscape indices aiming directly at evaluating ecosystem functionality as well as accounting for pressure on the dynamic of natural habitats.

In these two fields, the number of available indicators are very numerous, and one can find a review of biodiversity indicators for policy maker in Reid and al. (1993) (and a detailed list of biodiversity indicators used in UN (EU and OECD initiatives in Stevens and al. (2001).

For agricultural lands (Clergue and al. (2005) propose a review of methodological issues to assess biodiversity in cultivated areas, while Baudry and Burel (1999) provide a clear overview of the contribution of landscape ecology analysis to evaluate the role of agricultural land in conserving biodiversity.

In terms of biodiversity indicator framework, OECD used a Natural Capital Index (NCI) framework which is related to the PSR scheme. It deals only with wild-living species. Ten Brink (2000) presents this framework as follows :

The loss of biodiversity due both to loss of habitat and to pressures on the remaining habitat are called the loss of ecosystem quantity and ecosystem quality, respectively. Given these two factors the NCI framework has defined the natural capital as the product of the size of the remaining area (ecosystem quantity) and its quality:

NCI =ecosystem quantity * ecosystem quality.

Ecosystem quantity is defined as the size of the ecosystem (% area of country or region).
Ecosystem quality is defined as the ratio between the current and a baseline state (% of baseline).

The Natural Capital Index (NCI) ranges from 0 to 100%. For example, if 50% of a country still consists of natural area and the quality of this area has been decreased to 50%, than the $NCI_{natural\ area}$ is 25% (Figure 5). An $NCI_{natural\ area}$ of 0% means that the entire ecosystem has deteriorated either because there is no area left, or because the quality is 0% or both. An $NCI_{natural\ area}$ of 100 % means that the entire country consists of natural area of 100% quality

If there are no data on ecosystem quality available a pressure index may be used as substitute to provide an indication on ecosystem quality.

WWF proposed a composite index framework (the Living Planet Index) where biodiversity indicators have a central place. We shall complete the study of this framework in coming works in SEAMLESS. Further works could also pay attention to the projects EBMI-F (the European Biodiversity Monitoring and Indicator Framework), and SEBI2010 (Streamlining European 2010 Biodiversity Indicators).

5 SDI Frameworks specific to the agricultural sector

As suggested by the acronym “SEAMLESS”, relations between agriculture and environment are essential to SEAMLESS project. Agriculture is a major user of land and water resources. In many EU countries, it dominates and shapes the landscape through agricultural and social practices, resulting in a wide range of environmental issues at various scales. Among others, agri-environmental indicators (AEIs) can be used in this perspective, since they provide a "comprehensive information about the complex interactions between agriculture and environment" (reg 2078/92/EEC). For EU CAP, *ecologisation* of agriculture is also viewed as a way to integrate sectorial policies (EU, 2004). These challenges have already been identified at EU level, when the links between agriculture and environment were addressed collaboratively (EU Commission, Eurostat, DG Agriculture and DG Environment). The specificity of agriculture is underlined, and the necessity to amplify the conceptualisation of indicators is acknowledged (CE, 1999). As the CAP second pillar becomes more important, there is also a growing need to monitor agri-environmental measures by establishing "context", "trend" and "programme" indicators (Brouwer and Crabtree, 1999; EU, 2002).

This chapter explores the variety of indicators used in the agricultural sector when agriculture is related with environmental and sustainability issues. In the first of the four sections, we present categories of indicators to assess the sustainability of agroecosystems including: agricultural, agri-environmental, and ecological indicators that can be used in SEAMLESS. Secondly, we show how the choice of indicators depends on the underlying vision of the environment attached with disciplines or their integration.. The third section details initiatives corresponding to the previous categories of indicators identified and ways to represent sets of indicators. The last section includes a brief discussion on temporal and spatial scaling issues; it also opens directions for further work in specific areas.

5.1 Agricultural, Agri-environmental and Ecological indicators to assess the sustainability of agro-ecosystems

5.1.1 Sustainability of agricultural systems

Productivity is the most common attribute used for evaluation of sustainability (Lopez-Ridaura and al., 2005). Sustainability was formerly viewed either as an additional property to productivity, stability and equity (Conway, 1983) and later on as a more integrative property of agro-ecosystems (Conway, 1993a).

Yield trends are an obvious indicator to assess the sustainability of agricultural systems. However, the suitability of yield trends can be questioned:

(i) trends can be assessed by *ex post* analysis or by modelling however, sudden collapse may occur, (ii) yield trends are also highly specific to the site and to the crop variety, (iii) they usually cover small spatial scales and short time spans, (iv) they enhance one single aspect of performances (e.g. omitting product quality). Projections are risky since agricultural systems are dynamic and because a mere yield increase can have major environmental consequences.

5.1.2 Impact indicators

Among the methods used to assess the impact of agriculture on the environment and the rural landscape, several attempts have been made to design indicators. Impact indicators supply information on the effects of pollutant emissions. Depending on the position in the cause-effect chain in which they are defined, indicators can be *midpoint* (defined close to emissions) or *endpoint*.

In the past, many impact assessment methods focussed on one single environmental problem, such as pesticides impacts (Gustafson, 1989), whereas in the 90's new evaluation methods developed intend to integrate jointly several environmental issues (van der Werf and Petit, 2002). Emphasis has also been laid upon impact evaluation of agriculture, considering practices and/or their impacts, whether negative (e.g. nitrates in vulnerable zones) or positive (e.g. reduction of fire hazards and biodiversity maintenance in rangelands with grazing). When focussing on pollution problems, attention has alternatively been paid to the impacts of agriculture upon the environment (nitrates, pesticides, organic farm wastes,..) and to the impact of environmental pollution on agriculture (sewage sludge and other organic amendments, soil pollution and remediation..). In both cases, causal relations are generally not questioned. However, decision making about impact assessment is both a scientific and social activity, as mentioned by Capillon and al. (2005) in their literature review.

5.1.3 Agri-environmental indicators (AEIs)

The potential role of AEIs was acknowledged to answer a wide range of questions (Baldock, 1999). The OECD has developed such agri-environmental indicators (Parris, 2000). AEIs can offer a formal and routine manner of gathering and communicating information from a variety of sources (statistical survey data, mathematical models, expert opinion...).

The development of AEIs is formalised in a 3 stage process: (i) identification and measurement of underlying agri-environmental linkages and conditions (based on a dialogue among scientists and with policy makers: areas of concern, causalities, data availability), (ii) incorporation of AEIs into an economic framework to allow explicit consideration of trade-offs (methodologies for ranking and valuing agri-environmental goods and services), (iii) extension of the previous stage to the policy making arena (decision support tools, policy scenarios, interpretation of AEIs). The list of AEIs was arranged in 14 categories (contextual indicators, nutrient use, …) and used to compare countries and define trends with time series. These categories can be aggregated in 3 agricultural "fields" (see appendices 2.2.1 page 127):

- use of natural resources and farm inputs
- environmental impacts on compartments (soil/ water quality, biodiversity, wildlife, landscape..).
- interaction between environmental, economical and social factors: farm management practices, farm financial resources, rural viability.

OECD suggested ways to produce "policy relevant-analytically sound-easy to interpret-measurable" AEIs. In first instance, a "public-good" approach was used, taking into account the non-marketed assets or impacts of agriculture on the environment. The PSR framework was initially dedicated to environmental issues, in general: (i) considering various human activities (agriculture, industry, transport,..), (ii) distinguishing three different facets (Pressure, State and Response variables) and (iii) linking these facets through both causal and loop relations (OECD, 2000; Segnestam, 2002).

When applied to agriculture, this framework facilitated the process for arriving at a consensus of preferred AEIs. Subsequently, its value was not mainly in the precise categorisation of individual indicators (Parris, 2000).

The critiques of the PSR framework, and PSIR as well (Segnestam, 2002), include :

(i) suggesting linear relationships in the human activity-environment interactions (and therefore a dependency of socio-economic well-being on the state of the environment),
(ii) simplifying the relationships between the themes of sustainable development and how such themes are considered by different social agents,
(iii) omitting more complex relationships in ecosystems and in environment-economy interactions.

Such limitations can also be applied to the impact indicators previously mentioned.

5.1.4 Ecological indicators

Concerning environmental indicators for sustainability assessment, Becker (1997) differentiates three generations of indicators, mostly dedicated to policy planning and monitoring:

- The first generation of indicators can be called monofactorial indicators (of pollution or disturbance), including species that react sensitively to changes in the environment (such as "the canary in a coal mine"). This also opens the gate to biotic indicators (Buchs, 2003), now more referenced in scientific literature (*e.g*. Becker, 1995 and Albrecht, 2003 for plants; Paoletti, 1999 for invertebrates; Bouvier and al., 2002 for birds….), and used in agriculture for instance to compare the effects of various cropping systems..
- The second generation indicators focused on ecosystem dynamics, on the structure and function of entire ecosystems. This includes the assessment of values such as "ecosystem integrity", as expressed by the "Index of Biotic Integrity" (Regier, 1992), and "ecosystem health" presented earlier and discussed by Xu and Mage (2001),

These two generations can be called "ecological indicators", since their design is strongly anchored in ecology.

- The third generation includes socioeconomic aspects, where the concept merges with the one of sustainability indicators, appropriated by both environmental movements and international forums. This entails challenges in (i) combining indicators usually expressed in physical terms with monetary measurements and other valuations, and (ii) understanding the links between ecosystem health and social systems well-being (USDA, 2002).

Concerning sustainability indicators, Becker (1997) thus suggested to differentiate (i) ecological sustainability Dalsgaard and al. (1995) from environmental sustainability Van Pelt and al. (1995) and (ii) ecological indicators Rapport (1992) from environmental indicators. This leads the author to present 4 criteria for the selection and evaluation of sustainability indicators: *scientific validity, ecosystemic relevance, data management and sustainability paradigm.*

5.2 Representations of the agri-environment relationship

5.2.1 Views of the environment: analytical, constructivist or problem oriented?

As for the integration of dimensions of sustainability, the understanding of representations of the environment will determine both the selection and organisation of indicators. The segregation between components of the environment will differ with the agricultural production systems studied and will have consequences on potential trade-offs between impacts or objectives (Pearce, 1998). For instance, intensive indoor pig production would have to compromise between nitrate leaching and greenhouse gas emissions. Other production systems such as organic farming or integrated production include several objectives and attributes (such as risk management) and possibly another vision of the environment, with consequences on the assessment of biodiversity (Hole and al., 2005) and soil fertility maintenance (Mäder and al., 2005).

Environment can be described as a set of compartments and its level of decomposition varies widely. As a result, lists of thematic indicators vary accordingly. For example biodiversity can be alternatively considered through its functions (Clergue *and al.*, 2005), as a whole or divided (between natural and domestic biodiversity/ animal and vegetal biodiversity[3]). Conversely to a trend to increase the number of indicators, Azar and al. (1996) propose a comprehensive division of the environment in 3 compartments : lithosphere, ecosphere and technosphere. Based on four socio-ecological principles, the authors suggest physical indicators (as opposed to monetary indicators) :

(i) substances extracted from the lithosphere must not systematically accumulate in the ecosphere (3 indicators *e.g.* non renewable energy supply)

(ii) society-produced substances must not systematically accumulate in the ecosphere (4 indicators, *e.g.* production volumes of persistent chemicals)

(iii) the physical conditions for production and diversity within the ecosphere must not be systematically deteriorated (4 indicators *e.g.* nutrient balances in soils)

(iv) the use of resources must be efficient and just with respect to meeting human needs (4 indicators, *e.g.* overall efficiency indicators measuring productivity in the technosphere, detailed for food [proteins in food/phosphate input (world)]and energy)

Another way of approaching the environment in agriculture consists in focussing on environmental issues such as water, soil or biodiversity conservation/ preservation/ restoration. Issues can be site-specific and related with stakeholders (e.g. conservation of cereal-weeds in Luberon, South East of France) or more global (climate change). In this problem oriented focus, we can however differentiate “problem finding” and “problem solving” approaches. In the first one environmental issues are a social construction, and attention is given to the way stakeholders are involved in its definition, whereas in problem solving the environmental issue is taken for granted and positive solutions usually considered as accessible.

5.2.2 Resources and functions

Different visions of environment thus also reflect various descriptive conceptions of sustainability. With a literature review and an application to livestock farming systems, (Thompson, 1997) underlined the distinction between two approaches in terms of management of renewable natural resources in agriculture: "*resource sufficiency*" and "*functional integrity*".

The first approach identifies three classes of resources (abundant, renewable and critical) for time frames to be defined. This approach becomes dynamic with respect to critical resources, and prescriptions can be derived for resources conservation or substitution through the implementation of relevant technologies. Conservation requires either reduced consumption or increased efficiency, supported by technological development. Substitution is more controversial, opposing some economists presuming a high price elasticity for resource with ecologists who make the opposite assumption.

The second approach advocates a systemic vision enlarged to human activities. The crucial elements of the system (soil fertility, wildlife populations, even human institutions…) that are reproduced over time depend upon previous system states and therefore integrates explicitly

[3] In fruit production, relations can be established between vegetal and animal biodiversity: an optimal diversity in edgerows, with a limited number of species, would enhance the contribution of beneficial insects in order to reduce pesticides applications in apple orchards.

its dynamics. Human practice bears on such functional systems, including social forms of organisation that allow the system reproduction. Resources as not considered by themselves, but through the operation of the social systems based on these resources and ensuring their management and exploitation. Research should then concentrate on a better understanding of key resources and critical factors of systems dynamics.

These two approaches of sustainability give a different status to social and technical changes (preserving in a steady state *versus* enhancing transformation capabilities), and express different paradigms (anticipation *versus* resilience; combinations between scientific and local knowledge; technocentrism *versus* ecocentrism.).

How are these approaches translated into indicators?

The first approach led to the definition of environmental indicators, sometimes conceptually similar to economic indicators, in order to identify conditions and trends for natural resources (Azar *and al.*, 1996; Walker and al., 1996; Doran and Parkin, 1996; …). The second approach has not been translated extensively into sets of indicators but preferably into systems properties, although the Sustainable Rural Livelihood (SRL) framework further detailed (see Box 2) is one example. Dalsgaard *and al.* (1995) "selected four system properties that they consider crucial for sustainability - *diversity, cycling, stability, and capacity* - and they explicitly explained their selection criteria based on ecosystem theory" (Becker, 1997). They suggest ways and means to quantify such properties. This methodology was applied in a participatory process with local farmers. However, it is restricted to the local level - therefore facilitating spatial system comparison - but it does not consider other dimensions of sustainability. It focuses on state indicators, without considering trends over time.

The Natural Capital Index, developed as an assessment tool for the CDB (Convention on Biological Diversity), may represent an intermediate option between the two approaches: it is derived from ecosystem quantity (at various scales) and quality (relation between current and baseline state) (see details in section 4.3.3).

Among other possible approaches, a systemic relevant approach of AEIs could be provided in a territorial context with the concept of "landscape", as a cultivated and partly "half-natural" space within which agricultural production takes place and characterised by its biophysical and cultural components. This would enable to integrate a wide range of site-specific features and deal with systemic characteristics such as environmental quality or vulnerability. Such characteristics will be developed in chapter 5.

5.3 Indicator-based methods for agri-environmental assessment

5.3.1 General approach for environmental and sustainability assessment

Methods to evaluate environmental impact of agriculture, particularly at field and farm level, are well documented. These methods deal with one or several environmental issues. Comparisons can be implemented whether among systems in specific conditions (at a given period, in an area…), or to evaluate changes in a given system.

In a review of evaluation methods for environmental impacts of agricultural practices, Capillon and al. (2005) present (i) indicators-based methods, (ii) the procedure to select a method, (iii) the process to design a composite indicator, (iv) the issue of indicator validation.

The general hierarchical structure for the evaluation of *environmental impacts* is as follows (Lammerts von Bueren and Blom, 1997; Peeters and al., 2005; Capillon and al., 2005):

(i) definition of goals (ideal or improved situation) and of specific environmental objectives (with principles concerning functions of agro-ecosystems),
(ii) identification and definition of the system to evaluate,
(iii) identification or design of evaluation criteria for each objective,
(iv) definition of indicators or reference values (established on political, scientific or empirical basis) for evaluation criteria,
(v) interpretation of results (diagnosis) and recommendations..

Likewise, a protocol for measuring *sustainability* at the *farm level* (Gomez and al., 1996) would consist in: (i) defining the requirements for sustainability, (ii) selecting the a common set of indicators, (iii) specifying the threshold levels, (iv) transforming the indicators into a sustainability index and (v) testing the procedure using a set of data from selected farms.
For instance, Rasul and Thapa (2004) selected 12 indicators to evaluate and compare the sustainability of agricultural systems in Bangladesh. They aimed at representing ecological, economic and social dimensions of sustainability. Ecological sustainability was assessed based on 5 indicators: land-use and cropping patterns, soil fertility management and status, pest and disease management. The cropping pattern was in turn analysed using 3 criteria: cropping intensity, mixed cropping and crop diversification (measured through a "crop diversification index" Bathia, 1965).

5.3.2 Indicator-based methods for agri-environmental assessment

Van der Werf and Petit (2002) compared and analysed 12 indicator-based methods, referring either to farmer management practices ("*means-based*" indicators, which cost less in data collection but do not allow an actual evaluation of environmental impact, apart from ranking production systems) or on their effects ("*effect-based*", having a more direct link with objectives and therefore leaving technological choices opened). This can be extended to ecosystems theory and systems-based approaches considering processes and fluxes:

Four approaches are based on farming methods and land management practices, where a minimum value could refer to "Good Agricultural Practices":

FSI: practices-**score**-based Farmer Sustainability Index (Taylor and al., 1993),

Ecopoints: score-based method for both farmers production practices and landscape maintenance (Mayrhofer and al., 1996)

Indicators of farm sustainability (Vilain, 1999) assigns scores to farmer production practices and farmer behaviour, for the evaluation of agroecological, socio-territorial and economic dimensions.

Solagro DIALECTE diagnosis (Pointereau and al., 1999) yields performance levels for 4 "integrative criteria" considering: the number of production systems (animal and/or crop) within the farm, diversity of crops grown, management of inputs and management of space.

One set of approaches combines farming methods with environmental assessment:

- The AGRO*ECO and subsequent methods (Girardin and al., 2000) focus on the evaluation of potential impacts of arable cropping systems on the environment. A *double-entry* evaluation matrix defined includes 9 environmental components[4] and 10

[4] Renewable (water, air, soil) and non renewable (fossil energy and raw materials) abiotic resources, biotic resources (fauna and flora) and landscape.

agricultural practices[5], following Leopold and al. (1971) principles. Each intersection of the matrix corresponds to a relationship between an agricultural technique and an environmental component. This relationship is called and evaluation module, which can be aggregated to yield two types of indicators. *Agro-ecological indicators* reflect the impact of one production practice on all environmental components concerned, while *indicators of environmental impact* reflect the impact of all production practices concerned on one environmental component. The approach was further refined with INDIGO® (Girardin *and al.*, 2000), matrix approach with evaluation modules, fuzzy logic and software developments) and also applied to specific environmental issues (e.g. nitrate leaching).

Two approaches are grounded on systemic basis:

- AESA: Agro-ecological system attributes (Dalsgaard and Oficial, 1997). The approach is rooted in ecosystems theory, the mass-balance modelling software is used as a structuring quantitative tool.
- As a complement Capillon and al. (2005) mention the potential application of Ecological Footprint at farm level.

Three approaches are based on agri-environmental or multifunctional objectives:

- Multi-objective parameters (Vereijken, 1997), as indicators to quantify multiple objectives and design prototypes of sustainable ecological and integrated farming systems.
- Operationalising sustainability (Rossing and al., 1997) use multiple goal linear programming to optimise the objectives (environmental, economic, identified interactively with growers and environmentalists) at the farm level, including socio-economic constraints.
- Environmental management for agriculture (Lewis and Bardon, 1998). A computer-based system produces eco-ratings reflecting environmental performance and compares actual with local optimum practices. It incorporates modules to explore "what-if" scenarios and hypertext links.

Three approaches are based on Life Cycle Analysis (process-based environmental management):

- LCAA: **Life Cycle Analysis** for Agriculture (Audsley and al., 1997). LCA enables to estimate environmental impacts related to a product, process or activity (Guinée and al., 2002) and gives a mean to compare alternatives.
- Adaptation of LCA for the Sustainability of Energy crops (Biewinga and van der Bijl, 1996),
- Adaptation of LCA for environmental farm management (Rossier, 1999); it enables the identification of the main pollution sources and the evaluation of possible modifications of the farm or farming methods.

Halberg *and al.* (2005) report results and experiences derived from "green accounts" or *input-output accounting systems* (IOA) developed in countries with intensive production systems to facilitate voluntary improvements in farm environmental performance. Among 55 systems developed for environmental management in European farms (Halberg *and al.*, 2005), the 10 most promising IOAs were selected. Halberg *and al.* (2005) also paid attention to how such indicators fit farmers and advisors needs, in terms of (i) reference values for environmental

[5] Management of production factors (pesticides, nitrogen, phosphorus, water, energy, organic matter, soil) and spatial planning (cropping plan, soil cover, non-productive elements such as field margins)

performance evaluation, (ii) interpretation of the information given by indicators to foster changes in farm management (iii) link between IOA and production planning tools used by advisory services.

In a review on agro-ecology, defined as the holistic study of agro-ecosystems (including all environmental and human elements), Altieri (2002) points out the dilemma that exist between the definitions of location-specific *versus* universal indicators. A plausible option for measuring sustainability would be to start with a list of potential indicators from which practitioners select a subset of indicators that is felt to be appropriated for the particular environmental issue or farm type being evaluated. This position, which is part of an agro-ecosystemic view, will be considered in section 5.

5.3.3 Thresholds, representations and layouts

Tools for presentation and analysis of indicators include baselines, thresholds, targets and "comparators" (Segnestam, 2002). A baseline is a value that is determined before an indicator initiative starts in order to show a positive or negative environmental change as a result of the initiative. Thresholds can be used for monitoring systems based on alarms ("early warning") and diagnostic indicators when negative environmental impacts are anticipated. They can also reveal positive trends. With a reference to threshold levels (minimum value above which starts a trend towards sustainability), Gomez *and al.* (1996) used *yields*, *profit* and stability (*frequency of crop failure* or other disaster), while *soil depth*, water holding capacity, nutrient balance, *organic matter* content, permanent *ground cover*, and biological diversity were used as indicators of agricultural sustainability and resource conservation. Their farm-level indicators were based on the Framework for the Evaluation of Sustainable Land Management (FESLM), also being used in the "Land Quality Indicator" of the World Bank, which identifies 5 pillars of sustainable land management (productivity, security, protection, viability, acceptability). Indeed social acceptability is considered as more relevant at community level but it is not included as a farm-level parameter.

However the position of a threshold along a determining variable can change (Walker and Meyers, 2004): a case study on rangelands, described by Walker (1993) shows that the threshold ratio of shrubs to grass (slow-changing, controlling variable) is higher if the grass layer consists of perennials than if this layer consists of only annuals.

In contrast to work with optimal values, thresholds of sustainability, Lopez-Ridaura and al. (2000) produced indicators such as dependence from external inputs, grain yield, system adaptability, food self sufficiency, diversity of species.

Comparators aim at standardising information (relative versus absolute numbers; relevance to the message indicators are supposed to convey).

Polygons/Webs/Diamonds/Radars are widely used to illustrate graphically the relative sustainability of systems (Rigby and al., 2000b; Bockstaller and al., 1997). An AMOEBA-type diagram (Ten Brick, 1991) can be used to show how far, in qualitative terms, the objective has been reached for each indicator by giving the percentage of the actual value with respect to the ideal value (reference value). This enables a simple, yet comprehensive comparison of systems (or changes in systems) being evaluated or compared.

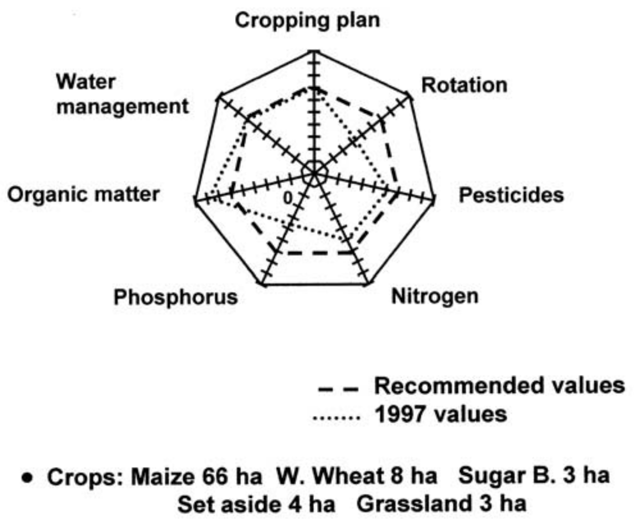

Figure 2 : Examples of "control panel" at farm level (Girardin *and al.*, 2000) and sustainability "Cobweb" (Rigby *and al.*, 2000b)

Displaying a number of indicator "scores" in this way avoids having to aggregate across different scales. The threshold levels used for all the indicators can also be based on the average in a community (Rigby *and al.*, 2000b) or in a sample of farms (Rigby *and al.*, 2001), based on recommended values (Bockstaller *and al.*, 1997) or potentially elaborated through consensus at community level (Rodrigues and al., 2003).

5.4 The Sustainable Rural Livelihood (SRL) approach

To address problems related to rural development, poverty reduction and environmental management, the concept of sustainable rural livelihoods has been developed. Different definitions can be found in Bruntland 1987. The main effect of the increased stress on rural development on existing SD framework is a better accounting for relationships between poverty and environment (Scoones, 1998), and the increased interest in how natural assets (including both material and social resources) can support the sustainability of rural livelihood strategies *i.e.* how can these natural assets support means of living. This focus on means of living and quality of life in rural area has lead to the separation of socio-economic capital into five capitals, besides Natural capital (nature’s goods and services): Social Capital (the cohesiveness of people and societies), Human Capital (the status of individuals), Physical Capital (local infrastructure), Financial Capital (stocks of money, savings, pensions physical, financial human and social capital) (see Box 2 for details).

Natural capital consists of land, water, and biological resources such as trees, pasture, and wildlife. The productivity of these resources may be degraded or improved by human management.

Physical capital is that created by economic production. It includes infrastructure, such as roads, irrigation works, electricity supply, and reticulated water, and also producer goods such as machinery.

Human capital is constituted by the quantity and quality of labour available. At household level, therefore it is determined by household size, but also by the education, skills, and health of household members.

Financial capital consists of stocks of money or other savings in liquid form. In this sense it not only includes financial assets such as pension rights, but should also include easily-disposed assets such as livestock, which in other senses may be considered as natural capital.

Social capital includes any assets such as rights or claims which are derived from membership of a group. This includes the ability to call on friends or kin for help in times of need, support from trade or professional associations (e.g. farmers' associations), and political claims on chiefs or politicians to provide assistance. These latter are sometimes discriminated as 'vertical' claims on structures of authority, contrasted with 'horizontal' claims among group members of similar status. The ability to make such claims may be considered as a mark of social inclusion or exclusion of particular individuals or groups.

Box 2: SRL five capitals, from Rigby and al. (2000a)

This approach was used to give an integrated frame to support the development of Sen's theories on human capabilities and on the three aspects of employment (income, production and recognition). Scoones (1998) proposes 5 key elements which should be given particular attention, to mobilise different evaluation means for these capitals:

1) Creation of working days (ability of a particular combination of livelihood strategies to create gainful employment for a certain period of the year)
2) Poverty reduction
3) Well-being and capabilities
4) Livelihood adaptation, vulnerability and resilience
5) Natural resource base sustainability

Applications of this framework have revealed its adaptation capacity to different scales, pertinent to a rural sustainable development perspective in poor countries. This is helped by the fact that these countries are mainly rural, so the economy and territorial organisation is largely based on the exploitation of natural assets. Rigby *and al.* (2000a) implemented this framework, largely within the Framework of Sustainable Environemental Land Management (FSELM), developing an indicator set for the levels of nation, district, village, farm and parcel: a list of the chosen indicators figures page 130.

Sustainability is seen in SRL as capacity to cope with and recover from shocks, while keeping these essential capabilities and assets, and the natural resource base, intact.

Key strengths of SRL approaches are that they:

- present a more realistic picture of rural life and of poverty, that provides a firmer base for designing effective interventions,
- provide a framework for assessing all aspects of rural people's assets, including 5 capitals,
- recognise that many players are involved in development at different levels - from central government ministries to local community organisations and the private sector. Such recognition paves the way for new partnerships between various types of institutions,
- emphasise that sustainability has many dimensions and is not limited to maintaining natural resource levels.

Some reservations about the value of SRL approaches include that:

- their ambition to work across orthodox boundaries may prove hard to fulfil in practice, as governments and donors tend to direct services along narrow sectoral lines although ecologisation of agriculture is an alternative path in EU (2004),

- given continuing food insecurity, agricultural productivity is still crucial to human wellbeing so detaching rural development from agriculture could be risky, especially when multifunctionality of agriculture and land use are at stake in EU,
- in theory they favour rich as well as poor and say nothing specific about distribution,
- such approaches are a re-hash of the Integrated Rural Development (IRD) thinking of the 1970s.

In response to the latter two criticisms, advocates of the SRL approaches argue that it can be used to target low-potential areas normally neglected by sector-specific approaches. And unlike the IRD approach, the newer approach is at heart participatory, involving thorough understanding of people’s livelihoods, and bottom-up rather than top-down planning. Furthermore, it does not entail the ‘abandoning’ of agriculture, but rather a refocusing on whether agriculture is the most effective route out of poverty for many of the rural poor (from Carney, 1998).

5.5 Topic discussion and directions for further work

5.5.1 Scale issues

The *spatial scales* in which AEIs are measured varies from field, farm, watershed, ecozones (Zurayk and al., 2001), regional, country and international levels. The distance between definition of international conventions and their application at a local level is problematic. Although indicators such as soil quality indicators (Karlen and al., 2001; see appendices 2.2.7) or "ecological footprint" can be applied at all levels, potential biases in calculations have been identified (Nijkamp and al., 2004) .

On the farming side, the links between field (or batch of animals) and farm levels are not always explicit. Some methods enable to compare or aggregate various field level assessments within a farm (Girardin *and al.*, 2000), others deal with intermediate functional units such as cropping patterns or with combinations of activities (Rasul & Thapa, 2003), whereas the Ambitec-Agro procedure (Rodrigues and al., 2003) begins with obtaining data for the magnitude of a technology (potential range and influence) and the activity or crop to which it is applied. It is acknowledged that indicators used at field or farm level can hardly be transferred at watershed level, due to availability of data (e.g. N measurements for each plot to establish N balances in Lacroix and al. (2005). For instance, compensation effects can occur when up-scaling: Bellon *and al.* (2000) showed that nitrate pollution which are attributed to horticulture can be compensated at community level by other land uses (apple orchards and meadows) located on different soil types (e.g. hydromorphic). In addition, risk assessment at higher levels will differ between indicators and models, especially according to how such tools account for the critical role of corridors and buffer areas (e.g. Haag and Kaupenjohann, 2001).

For a farming region, Payraudeau and van der Werf (2005) reviewed environmental assessment methods and selected six main initiatives: environmental risk mapping (ERM), LCA, EIA, multi-agent system, linear programming and AEIs. AEIs provide a framework to define a set of agro-environmental indicators, such as in the ELISA approach (environmental indicators for sustainable agriculture), where about 100 indicators are defined according to the DSR concept. Comparison of methods include (i) users-target groups, (ii) definition of objectives, (iii) indicators used to quantify these objectives, (iv) temporal variation and (v) spatial variability. The authors underline that assessment methods should include both local and global impacts in order to identify cases of "problem shifting" (e.g. reducing a local impact at the cost of an increased global impact). This is feasible with methods considering a sufficient number of environmental objectives (EIA and LCA).

From the OECD perspective, data need to be captured at an as detailed a level as possible and thereafter it has to be aggregated to the national level with some expression of the variation around the national indicator value (Parris, 2000), since indicators mainly refer to national entities. This entails a double *risk*: overemphasising national differences, neglecting common concerns; or focus on uniformity, ignoring fundamental structural disparities. The limits of integrating indicator values established at farm level or, conversely, breaking down of indicators calculated at a higher level are discussed by Payraudeau and van der Werf (2005).

Several authors advocate a *territorial* approach at sub-national and regional levels (Von Meyer, 2000). It is argued that such an approach would open policy options (for nature conservation, environmental protection), create potential synergies or conflicts among dimensions of sustainability and improve the capacity to test analytical hypotheses on the basis of specific cases. Two types of indicators based on a territorial approach are suggested, basic context and performance indicators and specific, topic related indicators (focussing on specific areas, addressing special development issues and policy concerns). This territorial scheme should be compatible with the NUTS classification (Eurostat). Emphasis should be laid upon new entities to analyse (i) local labour markets and local productive systems, (ii) eco-regions and environmentally sensitive zones. However, the definition and spatial dimension of such territories is still debated. Can they be defined without reference to a project and stakeholders? What do territorial "resources" consist of? Are farm territories a relevant level for analysis and planning? (Thenail and Baudry, 2004; Smeding and Joenge, 1999).

Muller (1995) reports the results of the development of indicators of sustainable agriculture in a watershed in Costa Rica, with a detailed methodology regarding issues of scale and dimensions of sustainability that should be assessed. Three levels are considered: plot, household and watershed. Three categories of indicators are defined: economic, social, environmental/ biophysical. Five dimensions are used to determine the sustainability of the systems, with different sets of the dimensions for different scales. The matrices that appear in the resulting analysis are illustrated at farm level in **Table 1**.

	Env/Biophysical	Economic	(Social)
Productivity			
Efficiency			
Resilience			
Biodiversity			
Satisfaction of basic needs			

Table 1: Matrix of combination between sustainability dimensions and properties for farm household level.

Temporal issues are also manifold. They are particularly related with inter *versus* intra-generation commitments, and time spans considered. Other related issues are in the processes considered (cyclic or cumulative), the extent of discrepancies between temporalities of the various dimensions of sustainability, as well as the planning horizon privileged. Azar *and al.* (1996) suggest two features that are important to take into consideration in relation to temporal issues for the construction of indicators

(i) there are in many cases long delays between a specific activity and the corresponding environmental consequences or damage. This entails that indicators based on the environmental state may give a too late warning, and in many cases they are only able to indicate whether past activities were sustainable or not.

(ii) the complexity of the ecosystems makes it impossible to predict all possible effects of a certain societal activity. Some damages are well-known, but others have not yet been identified. Most of the sustainability indicators that exists today are formulated with respect to known effects in the environment. Azar *and al.* (1996) therefore suggest that indicators of sustainability should be formulated to general principles or conditions of sustainability.

Confronting indicators, observations and models

Some restrictions also appear in the use of indicators, namely when pesticide use is the main environmental issue dealt with. OECD preliminary results on pesticide risks indicator (for aquatic environments in this case) showed that different indicator methods can produce different pesticide risk trends, even using the same data on pesticide risks and use (Parris, 2000). This was confirmed on apple orchards, with three production systems (organic, integrated and "conventional"). An indicator of the impact of plant protection was built, evaluating the intrinsic toxicity of all pesticides used on beneficial insects (Inra, 2003). It ranks by increasing toxicity organic, integrated and conventional systems. However, using another comprehensive indicator designed by Cornell University and taking into account the fate of pesticides in environment, the ranking is different: organic orchards are the last, due to the estimated toxicity and persistence of the forms of sulphur being used. This discrepancy in rankings also differs from biological field observations. As a result, the authors suggest controlling the use of AEIs with observations in real situations.

For another specific problem, *i.e.* the diagnosis of nitrate leaching risks, (Lacroix and al., 2005) confront the use of *models and indicators*. Following Mitchell and al. (1995) they argue that indicators were developed as an alternative to simulation models and with decision makers in view. Confrontation between SWAT model (Arnold and al., 1998) and a specific Indicator of Polluting Emissions (IPE) is implemented in a watershed. They conclude that the choice of a tool depends on the user's profile (and available knowledge: scientific expertise/ field based..), available time and means allocated to the diagnosis, time and spatial scales, initial problem and expected results (early warning/ identification of risk areas or practices/ explanation or demonstration..).

Bockstaller and Girardin (2003) also suggest methods to validate these indicators. They distinguish three dimensions of validation in: design (conceptual and scientific base), outputs (comparisons and expert judgement), and end uses (decision support for various users).

6 A SDI Framework For SEAMLESS.

SEAMLESS WP2 objective is to elaborate a tool, based on indictors, to assess the effect of different CAP options with a SD perspectives. A framework is necessary to organize such indicators in order to translate the general principles of SD, and to balance the specific aspects we want to emphasize. It allows to ensure a number of desirable properties for each indicator and for the global set of indicators are verified, or at least considered.

In SEAMLESS, we particularly need to emphasize :

- articulating the agricultural sector SD with SD of the rest of the society.
- Analysing different scales and their specific issues, as well as their interlinkage.
- Enabling to analyse separately different agricultural sub-sectors and policies, notably in order to make *ex ante* comparisons. This analysis should provide a global assessment of the policy as well as point each determinant elements influencing this assessment result, important to design policy.

From the literature reviewed here, we have notably retained that the systemic approach enables a complete and balanced SDI framework. It also seems to us to present advantages in dealing with the points evoked above.

After discussing in the first section the constraints related to the above preoccupations, the three next sections present the methodological choices leading to a flexible composite multi-scale systemic framework.

6.1 Implication of a sectoral and regional approach

Multiple indicators and contexts

Regarding methodological aspects, sectorisation and regionalization lead to an sharp rise in the levels at which indicators will be assessed which lead to an increased complexity of organisation and aggregation of indicators.

SEAMLESS has the ambition to do *ex post* analysis of the sustainability of the "whole" agricultural sector, as well as to conduct ex ante analysis of agricultural policy options, with a focus on specific sub-sectors of agricultural activities. That increases the number of indicators that might be relevant to SD, but also the number of sub-sectoral contexts that needs to be taken into consideration. Moreover, the main initiatives producing SDI related to the agricultural sector, have been conducted in an *ex post* context and with a much smaller scope than what SEAMLESS aims to do. This extensive scope of SEAMLESS increases the problem of contextual irrelevance of indicators by multiplying regional, local and sub-sectoral contexts. This has numerous methodological implications for the choice and the aggregation of indicators.

A major problem is that to respect scientific soundness of methodology, in a aggregative approach using weights for variables or sub-indicators, every weight has to be set in almost every regional, local and sub-sectorial context otherwise the stability of the weights between contexts has to be demonstrated. Note that if there are two many situations in which different weights have to be determined for SEAMLESS, it is the final user that has to be able to determine what weights and sub-indicators are relevant in the considered context. So this question is a pragmatic concern and maybe WP1 should provide a finite list of sub-sectors on which SEAMLESS-IF is expected to produce its *ex ante* policy analysis. This in order to assess as quickly as possible if an exhaustive work on weights is possible to perform within this project.

Multiple scales of analysis and aggregation

Due to different approaches on SD from different disciplines combined with the complexity of SD assessment for agro-ecosystem, the scales of analysis are numerous and redundancy can easily appear between indicators at field, farm, local, regional, national and supra-national levels. The existing and used Frameworks assessed in this paper have not addressed this very essential question for the agricultural and regional context. Reviewed initiatives propose list of indicators with different levels of indicator assessment (Farm, Region, Country, …), but with little detail of links between these scales. Instead at each scale, attempts are made to evaluate SD performance, often using analogue state indicators, but without integrated attempt. For instance, an analogue indicator can contribute differently to the SD performance at different scale.

To illustrate this problem lets consider the farm level and the field level, which are very different from the others which are spatial levels of SDI production. The farm and the field levels of analysis are more typological (statistical categories). So the final number of indicators depends on a choice of the number of agricultural systems or practices analysed. Preceding works using such ”scale”, often confine them to environmental thematic indicators, and sometimes couple them with economic profitability indicators.

Agriculture, territory and SD

One important question is about the meaning of sustainability and the spheres where it has to be estimated. Within the scope of SEAMLESS, *ex ante* policy relevance is expected as related to CAP and environmental policies. It implies that only effects caused by the agricultural sector are accounted for. Thus, when effects are mainly due to agriculture, pressure and state indicators are of equal relevance. But for effects shared with others economic sectors, the pressure exerted by the agricultural sector and the global state indicator don't have the same status.

If we look at indicator initiatives focussing on different sectors, it is possible to see that those relative to agriculture are much more complex: in the territorial typology, and in the categories differentiating indicators of sectoral effects and other effects. At the heart of this complexity lies the notion of rurality. Rurality regards communities as well as territories; this ambiguity makes scale and reference population choices more complex. When regarding economic and social indicators, such as income: should it be estimated for agricultural workers and their family, or rather for the rural community living in the space where agricultural policies are implemented?

Rurality is not only about spatial scale and community. When differentiating sectoral effects, rural effects and effects on the rest of society, the question of functionalities relative to the rural system clearly appears. This can be illustrated by the SRL concept used in developing countries, or more generically by the question of multifunctionality of agriculture. However, for regions where SRL has been implemented, the delimitation between communities and spatial areas are easier than for EU. Clearly, this question has to be motivated in each thematic SD indicators of SEAMLESS, and with a motivated conceptualisation of the delimitation between sectoral and rural effects. Regarding the calendar of SEAMLESS, it seems difficult to produce a sound conceptualisation, convenient for all the disciplines involved in WP2. The complexity of the question, has led some initiatives to consider rurality itself as an indicator. As a consequence this leads to choosing the pragmatic way that consists of unambiguously answering three questions:

- At regional scale, what is, the available data at the EU-level for SEAMLESS. Which are the variables and which are the spatial entities that can be considered as candidates to identify the different communities relevant to rurality in order to disaggregate data?
- What kind of distinction between sectoral and rural effects, do these spatial entities allow to address?
- And finally, can we produce some satisfactory conceptualisations, regarding SD, of these distinctions?

6.2 A systemic framework

One of the principal issues in the construction of an SDI framework is the composition of each pillar. As we have seen, we can distinguish four approaches, a composition by components (ex: water, air, earth...), by issues (water pollution, erosion, ...), by Pressure/State/Impact/Response (DPSIR, PSR, ...) and by systemic properties. Besides, it is frequent that the compositions by components or by issues are combined with a frame distinguishing variables of state, impact and response. Conversely, crossing systemic properties and other decompositions call for conceptual work because the systemic property approach generally aims at delivering a frame that lists all necessary and expected properties of a system. Indeed, issues and components constitute a rather straightforward partition, stable when articulated with an exterior frame such as PSR. The systemic logic implies functional coherence which calls for modifying such partitions.

Elements from agro-system literature

As pointed out by Hansen (1996), two conceptions of sustainability have evolved in parallel: sustainability as an ability to satisfy goals (for instance those defined by sustainable development principles), and sustainability as an ability of the (agro)-system to continue. This leads to numerous definitions of sustainability, which entangles and complicates the use of various works on agro-system sustainability in the development of a SDIF. It is particularly true from two standpoints:

- the integration of the 3 SD pillars,
- the links between agricultural system and the total system, i.e. the whole economic, environmental and social system.

A majority of agro-system SDIF reviewed here assume that “the protection of agricultural production system is postulated as a major aim” (von Wiren-Lehr, 2001) and sustainability is defined in agro-system literature as the ability to maintain “the economic, biological and physical components that make up the system". It’s clear that from this starting point, the attention paid to the socioeconomic aspects is limited, restricted on those aspects dealing with the sustainability of the agricultural activity, with a specific focus on agricultural land and agricultural population. The effort made to identify systemic properties that assure sustainability, even in the initiatives that want to develop further the economic and social aspects, have produced a limited set of systemic properties for the economic and social pillars. The pioneer work of Conway on systemic property to assess agro-system sustainability integrates the social pillars only through the notion of equity. Conway’s followers have introduced more and more property that can be used easier within the three pillars, but with the same starting point, the bias that consists of a focus on agro-system sustainability understood as its ability to maintain itself. This difficulty to really embrace the SD paradigm is mainly due to the difficulty of agronomic models to deal with policy level[6] (and consequently to organize response indicators), and to consider the “outside-exterior” of the agro-system not only as a constraint or as an impact, but through an interacting relation.

One way to better consider the outside of the agro-system and the interrelations between the agro-system and the system in which the agro-system is included has already been attempted by the SRL framework. Focusing on rural community of developing countries (where the agro-system is the heart of the community organization) with a livelihood perspective, forces to deal with all of people's conditions of living, including those governing the farming system. In this framework, the consequence of different policy options, for example on intra-community relations (agricultural and non agricultural workers), on resource access, equity, etc., are addressed. Moreover, the generation of agriculture off-farm income, emigration and remittances have to be looked at together, including the increasingly important rural-urban linkages in the wider economy (Scoones, 1998). This framework is however unsuitable to deal with regions formed by urban, peri-urban and rural area, where the objectives of SD are more complicated because development is not only centered on rurality and agriculture. Moreover the framework develops a specific indicator thematic based on basic needs (number of working days, poverty, capabilities) that are not sufficient to deal with all the questions raised by sustainable development in developed countries.

Dealing with two systems

The problem of creating a framework suitable for SEAMLESS needs and constraints is not only to call into question the postulated primary aim of protecting agricultural systems, but to build a framework that articulates this aim within a global ambition of sustainable development (at different scales). Considering fist a given scale, independently to its relation to other scales, and given the available frameworks reviewed, we conclude that a systemic approach could help us to overcome this problem by noting that:

- we have to deal with two systems : an agricultural system and a total system which includes the first one. However both systems are dealt with differently, since agriculture is the focus of the study. So the agricultural system is assessed more thoroughly (3 pillars), while the total system is considered through the relation it (not split into pillars) has with the 3 pillars of the agricultural system.
- a list of properties is expected, (i) in each pillar of the agricultural system, (ii) and for the contribution of each these agicultural system pillars to SD of the total system (existence, effectiveness adaptability, freedom, security, co-existence, psychological needs; see section 4.1.4.2)
- for each pillar of the agricultural system, we have properties that assess the considered pillar (5/6 properties), and the relation to other pillars (one property – coexistence).

Note that the word "contribution" is used here to relate that the aim in SEAMLESS is to ameliorate agricultural practices and policies towards integrating the more general SD perspective of the total system. The relation between both systems is the focus of the second list of properties, including the implicit concern from the total system SD perspective for the viability of the included agricultural system.

[6] Scales at which conception and implementation are made, as well as broader objectives and perspectives are dealt with.

Systemic properties for the two systems

The systemic properties elaborated by the Balaton group, then developed by Bossel (1999), give an interesting framework, but difficult to interpret at all scales and situations that SEAMLESS has to deal with. It is generally advanced that these difficulties are due to the strong uncertainty whether indicators can be identified for all expected properties, that are pertinent for agro-ecosystems of the different regions considered and that have sufficiently strong links with the effects of the agricultural policy options that are tested. This difficulty, if it is one, can be reduced by an effort to translate these systemic properties so they respond more directly to an agro-ecosystemic perspective. However the price of this exercise is generally some loss in generality of properties. They will no longer relate smoothly with SD preoccupations relative to other systems exterior to agro-environmental systems. Note that the agro-ecosystemic perspective we are talking about is not a simple derivation of sustainable development properties to fit agriculture. The agricultural system is a part, a sector of the whole system, its scope is reduced. The agricultural system perspective is that of agricultural maintenance, what are the conditions and balances enabling the sector to maintain. The SD perspective is more general, and implicitely contains the sectoral perspective, but balanced against other related and non directly related preoccupations.

However, to overcome this problem, we analyse the contribution of the agricultural system to the SD of the total system through general systemic properties (Bossel, 1999), thus dealing with each system with properties adapted to their scope. A first "**total system**" enabling to encompass global sustainability of society, economy and environment where the framework proposed by (Bossel, 1999) is suitable. And an **" agricultural system**", included in the first "**total system**", which articulates proprieties specific to agriculture, rurality and agro-ecosystems. These can be elaborated from major works on sustainability agro-ecosystemic properties (see appendices 5 page 149, and chapter 5), when they advantageously replace the general Bossel properties.

In the framework proposed by Bossel (1999), the properties of each system to assure their own sustainability constitutes only half of the indicator list. For each pillar, there is an indicator to assess contribution to each systemic property of the total system. To summarize, there are two levels of interlinkage (see Figure 3):

- an interlinkage between pillars – taken into account by the co-existence property- , this could for example be an indicator that shows how some environmental components of the agricultural system can contribute to the economic pillar of the agricultural system.
- an interlinkage between agricultural sub-system and total system, which shows how each pillar of the agricultural system can contribute to each systemic property of the sustainability of the total system.

These interlinkages have not been systematically integrated in preceding works on SDIF for agro-systems reviewed here and to overcome this gap could perhaps be one of the most interesting and promising challenges for WP2. The preceding works identify some of the properties of the first column of the agricultural sub-system in Figure 3. However, the distribution of these properties in the different pillars in Figure 3 is not straightforward from these works. Indeed, these agro-systemic properties were not conceived with pillars of SD in mind, so it would be incoherent to simply reproduce the list in each pillar.

For instance using MESMIS as a starting point, the proprieties "productivity" and "equity" can be respectively re-affected to the "economic" and "social" pillars, things are different for others properties such as "stability, resilience, reliability" which are applicable to all three pillars (they echo Bossel's security-adaptativity). A reflection on these works could be engaged within WP2 to identify precisely how to balance expected properties of agro-ecosystems within each pillar. Concretely, the adaptation to SEAMLESS needs is done in the following way. For the property lists corresponding to the two systems, we consider the complete Bossel (1999) properties. For the agricultural system, we analyse how agro-ecosystemic properties from literature, distributed in the SD pillars, represent a derivation of the properties proposed by Bossel (1999). Where non represented Bossel 1999 properties are still relevant in the agricultural system, we keep them.

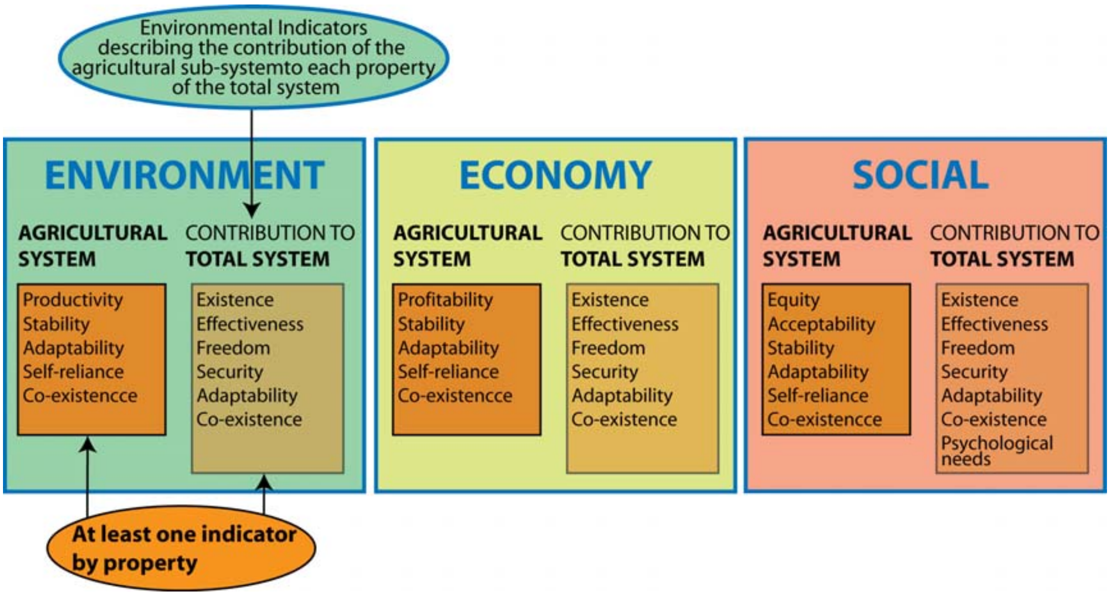

Figure 3 : proposed systemic properties in each pillar

We thus propose a first methodological option aiming at articulating two systems, a "total system" and a "agricultural system". The total system is used only to account for the contribution of (relation between) the agricultural sub-system to the sustainable development of the whole system, and would very directly use the systemic properties of Bossel (1999). The description of the properties of the agricultural sub-system rely on the precedent exercises of agro-system sustainability evaluation at the scale of farm (Lopez-Ridaura *and al.*, 2005; Gomez and al., 2000; Rigby *and al.*, 2001) and of rural community (Smyth and Dumansky, 1995), trying to propose translations of Bossel's proprieties fitting the thinking frame of agricultural system by ecological, biotechnical and social sciences. These properties are then used at all scales for the agricultural system. We present a first suggestion concerning proprieties associated to this agricultural sub-system in Figure 3.

The advantages of such a framework are:

- It conserves a separation by SD pillars that enables to discuss expected balances between the environmental, economic and social aspects of SD,

- It articulates two approaches of sustainability: sustainable development of the total system and sustainability where the agricultural system and its activity is in the centre, and thus already permits to engage an *ex post* analysis of the relations between these two systems.

6.3 A 4 + 1 scales Framework

The applications to the agricultural sector of SDIF reviewed in this paper, involve different analytical scales, from parcel to nation, passing by farm, town (community), rural zone and region (administrative or bio-geographic). The choice of scales should be adapted to the scales of considered phenomena in society (economy, social) but also to scales related to ecosystem functioning, to scales where data is available, and to the different scales of policy implementation.

For several reasons it is important to present indicators at different scales. The most determining, given SEAMLESS objectives are to account in a more thorough and coherent way for studied phenomena, be they economic, social or natural[7]. Another reason is to aim for a better link between the scales of the framework and the scales of policy implementation, in order to clearly identify responsibility of policy makers at each of these scales.

The different scales used in agricultural system studies

In works on SDI it is possible to find a division of scales corresponding to "type of farm" – "region"- "nation" (Rigby *and al.*, 2000a; Farrow and Winograd, 2001). The possibility of relying on such a division in SEAMLESS remains pertinent provided it integrates a measure at Europe global scale and a measure of effects induced on the rest of the world. The scale "(type of) farm" has a particular statute, since it is the only "scale" of analysis that is not territorial. Moreover, regarding the distinction proposed above between agricultural sub-system and total system, the farm scale has only one system: the total system reduces to the agricultural sub-system (see Table 2). So the contribution to the SD of the total system is absent as far as the formal framework with SD properties is concerned (this could be discussed). The perspective fully considered at this scale is that of the agricultural system's maintenance. The larger SD perspective is more difficult to integrate, because it involves relations with phenomena set outside the farm and farmers and families. For the time being, it is through the relation of this scale to higher levels (scales) that these concerns can be dealt with, notably concerning the social pillar, how conditions at the farm scale may determine policies at community level for instance, or how decisions taken outside the farm may induce particular behavior or conditions for the farmer and/or his family.

So This "farm" scale, at which most agro-systemic studies are lead, seems unavoidable although it introduces particular difficulties. Because of the difficulty to embrace a general scope at this level as explained above, we reject the possibility of basing regional sustainability evaluation on a simple aggregation of sustainability indicators at the farm scale. This leads us to propose a framework that leaves open at this stage, the articulation of this farm scale with the other scales (that are territorial, and distinguish the agricultural system in the total system). In this line, the relation between all scales is not completely modelled in the framework proposed. We direct to task 2.6 – dealing with questions about aggregation of composite indicators –, to pursue the reflection on articulating the obtained indices between the "farm" scale and above scales, and more generally on organizing the representation and influence of (indicators of) one level on another.

The other scales are territorial in their definition and the difficulties in the adaptation of the framework at every scale lay essentially in the distinction between agricultural system and total system. Within the agricultural system, each pillar should account for its links, whether

[7] In addition to the fact that many phenomena have a meaning at certain scales only, some modelizations or data are only available at certain scales.

dependence or support, with other pillars through the coexistence property. Concerning the relation between both systems, we consider the total system only through the contribution (relation) of the agricultural system to SD of the total system. This is done by assessing the contribution of each pillar of the agricultural system to each SD systemic property of the total system. Note that this contribution can relate to the same pillar of the total system, or another.

Scales and agricultural system definition

We can build delimitations relative to the agricultural sub-system through spatial definition (agricultural land versus the whole territory) or territorial definition (rural zones versus urban zones), but also by population category (farmers versus total population) as far as data relative to the economic and social pillars are concerned. Following the scale and pillar considered, the definition of the agricultural subsystem will have to cross these different delimitations to account for relations between the two systems.

The definition of the agricultural subsystem, induces in the total system a distinction of agricultural space, population, and concerns. How this boundary is defined may emphasize one or the other of these distinctions, and certain relations and tensions in society (this is exemplified in the next paragraph). Since we consider important to assess at all levels conditions and scale specific levers for farmer's subsistence, the agricultural system is defined across all scales as agricultural land and farmers (working and living on the farm) and their families. So the specificity of the different scales is not in the definition of the agricultural system, but in the emphasis on particular phenomena within the contribution (relation) of the agricultural system to SD of the total system, echoed in scale specific links to other scales. This is why, although it is costly to adopt many scales, the fact of assessing phenomena at their appropriate scale may avoid or help representing it at another, which my be incomplete and even complicated depending on the relation between scales to be modelled.

For the "community" (village, ... defined below) scale, we can privilege the population distinction to assess relations between farmers and the total population within a rural community. For this, the total system is the community. We define the agricultural system as agricultural land managed by farmers and their families, that is an aggregation of farms in or depending of the community. This "community" scale has its particularities. We mean by community the first elective scale at which people are organized in a community. This scale is important because (i) it could help define a rural zone in which many of the different usages of environment (notably among those linked to the multifunctionality of agriculture) take place, (ii) it is the scale at which take place direct relations between people (local power organization, water use tensions,...) , appropriate to account for quality of life. Rurality seems to find most of its meaning at this scale. We precise first available elective scale, because both availability and political organization may vary following the country. . Social organisation and relations will be assessed in the contribution-relation to the total system (apart from those indicators relating in the agricultural system the social pressures from the community that determine behavior on the farm, depending on the relation between scales).

The farm scale and community scale (with embedded farms) enable us to assess thoroughly respectively agricultural practices and rurality concerns. This is because the community corresponds to what we will consider the rural zone, where most of the relation between agriculture and society actually takes place. Thus since the agricultural system definition limits it to farms at all scales, representing the rural relations assessed at community level, at higher levels, is an essential task for modelling the links between different scales.

There is more than one way of defining a rural zone (or rural area). The first is following a landscape definition of agricultural land, and using a ratio of agricultural land over total land to decide whether the zone is rural or not. The second is following the weight of agriculture in the economy of the considered area. A third uses the distance to a defined "work bassin" where more jobs are available. If it is possible to define a rural community (data available at such a scale), being the fisrt available elective scale, we can at above scales consider the aggregation of such rural communities as the rural zone corresponding to the agricultural system.

At the regional scale, this delimitation thus involves a territorial distinction between rural zone and urban zone, and would rather emphasize relations between them. Note that this relies on determining rural communities and thus rural zones with available data, which may not be possible. As a consequence, the capacity of the regional scale, which could be the minimal mesh for data on economic and social pillars, to ensure accounting in that case for relations between farmers and other populations in the rural setting can be questioned. Hence particular attention should be given to regional scale indicators susceptible of capturing part of these relations. We could then, select indicators, using a double division of relations between the agricultural sub-system and the total system: agricultural land/rural area.

Scales of nation and Europe are defined with an analog agricultural system, simply aggregating rural zones of the inferior scale.

Without being as problematic as the problem with the farm scale, the difficulties of integration between different territorial scales, remain at this point unsatisfactory in existing initiatives and calls for developments in task 2.6. At present stage it is therefore important to create a set of indicators that covers link between scales, rather producing indicators that are constructed through an aggregation from an inferior scale to a superior scale for instance. The pertinence of indicators at each scale has thus to be thought independently. It is however clear that many of them will be the same for different scales.

Note that the particular emphasis put on phenomena of different nature at different scales could guide the elaboration of link between scales. That is agricultural practices at farm scale, multifunctionality, quality of life or tension between farmers and neighbours at community scale, rural-non rural usages of environment at regional scale...For instance, the agricultural practices assessed at the farm scale could be accounted for at superior scales, by simple statistic aggregation of indicators, or by reinterpretation, representation of relevant consequences for decision at the considered scale... The same can be done for scale desaggregation, reporting information from indicators at above scales with indicators that are sound for decision.

We thus propose a second methodological option where 5 scales are used. An analytical scale by type of farm, with an organization of indicators within the lone (merged with the total system) agricultural system. 4 territorial scales where the two systems are defined in the Table 2.

The analysis of questions about aggregation are to be pursued in task 2.6, and the selection of indicators at each scale should be thought independently, bearing solely in mind to identify the indicators that answer at best the sustainability proprieties at the considered scale. We propose in addition to produce a series of indicators on the distribution of sustainability indices at each scale (such as median, min or max), susceptible to reset for instance the value of a composite indicator for a region relatively to the value of this indicator in other regions (see Figure 4)

	Agricultural System	Total system
Farm Scale	Farm type	
Community Scale	Agricultural Lands	Community
Regional Scale	Agricultural Lands	Region
National Scale	Agricultural Lands	Country
European Scale	Agricultural Lands	Europe

Table 2: Scales for the two systems

6.4 A composite Framework

The initiatives of indicator lists that have been assessed in this paper show, an inflation of the number of indicators over time and this phenomena has been accentuated with the development of regional and/or sectoral SDI. Eventually to long indicator lists turn out to be unusable (Lopez-Ridaura and al., 2002) and it is possible to observe, since 2000, a methodological effort to reduce these lists. This effort has concretized in the elaboration of multi-level frameworks where different levels of indicators are identified, with a hierarchical approach of issues, using different aggregation levels in the most advanced initiatives, articulating simple indicators and composite indicators. Composite aggregated indicators are appreciated because they enable easy communication and provide a univocal indication on the direction of one or another option of sustainable development, but the methodological requirements they involve do not permit to integrate certain phenomena who only have uncertain participation to the 3 pillars of sustainable development. We hence should elaborate a framework enabling to read on the one hand aggregated indicators, sub-indicators integrated in their calculation, and on the other hand a complementary set of "second order" sub-indicators and variables describing contextual elements susceptible to play a role in implementing agricultural policies or rural space management.

This three-way approach, in *addition to the interpretation model* it provides enables us to build a hierarchy for sub-indicators, which makes it possible to develop statistical assessments later on (sensibility analysis, multivariate regressions) to identify contexts in which regularities in the contribution of certain of these "second order" indicators to sustainable development[8] can be found (Esty *and al.*, 2005).

Then, it has been advanced that sub-indicators best adapted as candidates to composite indicator construction could be very different, within each pillar, following geographical zones and/or agricultural sub-sectors considered. We thus need a framework disposing of a user interface enabling to adapt composing sub-indicators to the context. Such a design implies a few constraints:

- that we proceed to the normalization of sub-indicators, and that the sign (+ or – depending on its contribution to each pillar) of each sub-indicator is taken into account, so that eventual contextual substitutions finally permit comparisons between composite indicators aggregated from different sets of sub-indicators,

[8] Note however that contextual indicators are integrated in the aggregation in 2005ESI (Esty and al., 2005).

- that a corollary to the normalization constraint is that many sub-indicators coming from qualitative variables can not be candidate to this aggregation process and thus will have to be part of the complementary set of indicators. This point can seem damageable to the institutional pillar where most variables and indicators are of discrete type. Two directions can be considered:
  - adapt a more rigid frame for aggregation within the institutional pillar where all candidates to aggregation would be always the same in order to produce comparable scores – for instance using institutional indicators coming from works in the 2005ESI,
  - and/or use all or part of institutional variables uniquely in a second step within the phase of result interpretation; notably within the statistical development and sensibility analysis in order to identify institutional contexts that help sustainable development and how they articulate. It seems to be the option retained in PD2.4.1.
- That an equal weighting aggregation procedure is adopted, and if not, the possibility be left to the user to choose the weight of each sub-indicator provided the total sum of weights stay constant.
- That a minimal and maximal number of sub-indicators remain fixed, and that only a "recommended" number of sub-indicators participate in the construction of the composite index, and that the aggregation procedure make the number of sub-indicators neutral.

We therefore propose a third methodological option. Following how they satisfy our criteria of selection, indicators will be inscribed on the list of candidates (list of sub-indicators) to composite indicators elaboration, or on the list of complementary indicators and variables. The wide range of indicators elaborated in tasks 2.2.2 to 2.2.4 on thematic indicators, should be sorted between these two lists for each scale and pillar. The complementary list will only be used for post-analysis of the results. The construction of composite indicators only uses the list of sub-indicators. For each of these sub-composite indicators, the systemic properties to which they may contribute and how, will be identified at each scale. Depending on which pillars, scales and analyzed policy options, the user will select a series of indicators on the list of composite elaboration candidates. These will be normalized (methodology to be determined in task 2.6) and the sign of their contribution to SD will be defined.

Two options remain to organize the relative importance of a particular property for a given policy analysed : select more than one sub-indicators for a property or adjust the weight given to the property with one sub-indicator (with a constraint on the sum of the weights).

If more than one indicator per property is necessary, a further choice has to be made as to aggregating these into a single aggregated indicator per property or not, and what this property-specific scheme of aggregation will be. More generally, and amid the parsimony principle, in finding indicators representing properties (or fitting available indicators in the systemic framework), some hierarchical construction of sub-properties or themes leading to more specific indicators will be used. Indeed, a simple available indicator for each property can not always be derived, as a best representative, a key indicator, or a weak point in a more strong sustainability perspective. Thus, in addition to the scheme necessary to aggregate an indicator per property into composite indicators, aggregation schemes corresponding to the hierarchical construction of composite indicators representing one property have to be derived. These two schemes can be independent, or not, following how the relative importance of different properties is dealt with. These questions should be further treated in task 2.6 . Note that this problem is independent of the fact the proposed framework is systemic. When organized by themes, general themes correspond to the systemic property level, and further hierarchical construction into subthemes leading to more specific indicators is also necessary.

This approach enables to combine an adaptability to the context with the comparability of composite indicators (such an adaptability can be realized through participatory methods). It also validates the approach that had been chosen from start in SEAMLESS to resort to 4 pillars (economic, environmental, social and institutional) with a specific statute for thematic institutional indicators of the fourth pillar which can take advantage of the complementary list of indicators.

Methodological options relative to how the selection of indicators should be organized to cover the SD problematic and if certain sub-indicators should be proposed or imposed on the user is discussed in the following section 6.5.

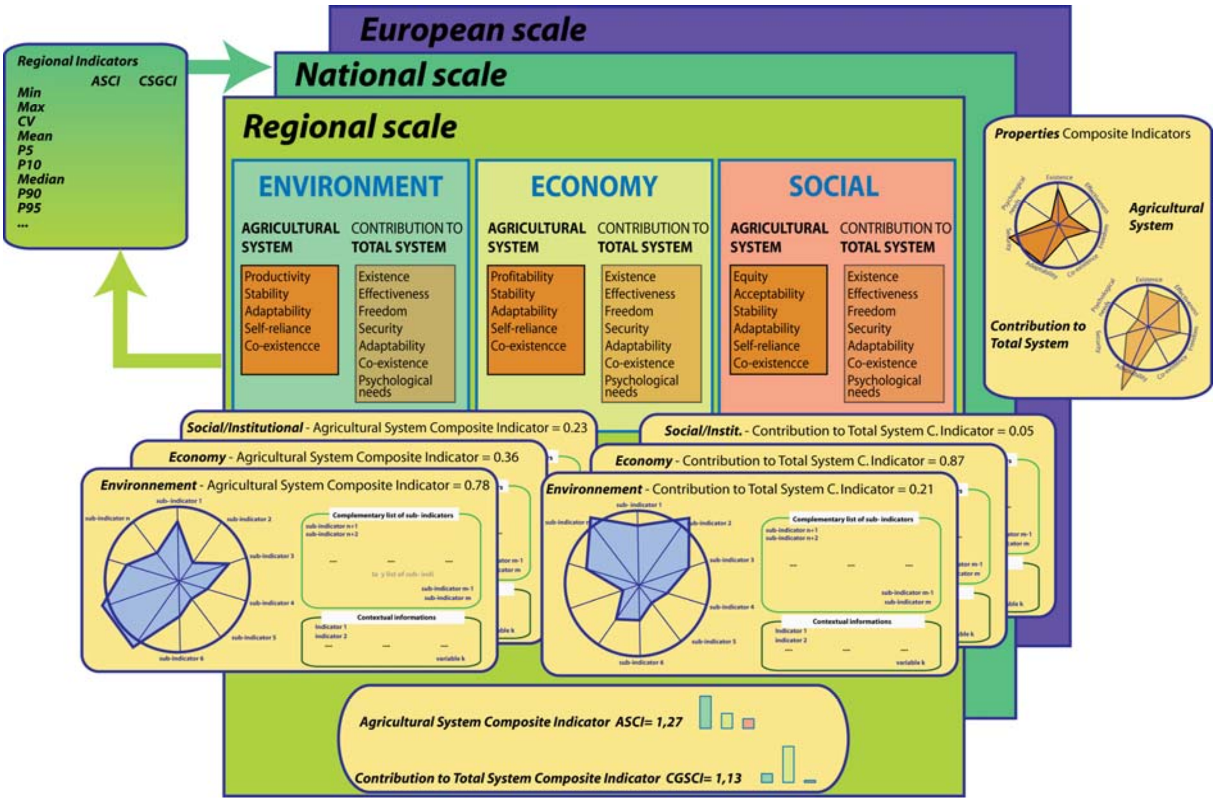

Figure 4 : organization of the framework at a given scale (farm and community scale not represented here)

6.5 Implementing the framework and policy relevance

Figure 4 illustrates at a given scale (here the regional scale) the organization of the indicators that are to be selected and how they might be aggregated and presented.

At a given scale, we have a table organised by properties. One can wonder how to select adequate indicators that fit general properties, and enable a comparative policy analysis.

Two points are confusing at this stage of the presentation of the framework:

- Can the same grill be used for *ex post* analysis of agricultural sustainability and how it contributes to sustainable development, and *ex ante* analysis of comparative sustainability of competing agricultural policies?
- Does the user have to identify the adequate indicators him or herself and how is it possible to make sure that this selection will correspond to each of the proposed systemic properties as well as how these properties relate to the users policy concern?

The answer to both questions is that SEAMLESS has to propose an organized pre-list of candidate indicators to be chosen from. The organization of this pre-list will be one of the major tasks to make the framework usable This work is also crucial for how SEAMLESS will deal with the requirement of policy relevance.

This pre-list has to be organized by policy field of the CAP, and differentiate *ex post* and *ex ante* purpose. If we consider the actual indicator lists that are discussed and proposed in task 2.2, 2.3 and 2.4 respectively, they can provide at each scale a interesting base to identify indicators, for each systemic property, which finally may allow end-users to address the *ex post* sustainability of the agricultural system and the *ex post* contribution of the agricultural system to SD. However, they are not sufficient to make *ex ante* or *ex post* comparative analysis of specific policy options. This is because they were not elaborated for separate *ex ante* analysis of a particular policy, where indicators should also emphasize phenomena that determine policy implementation and point to respective advantages and drawbacks of competing options.

Completing these lists to allow *ex ante* analysis is a hard and long work, that requires to define the number of policies or policy fields as well as policy options within each field that SEAMLESS will deal with. It therefore seems unavoidable that WP1 and WP7 engage in defining what are or will be for the end-users the main CAP policies, not forgetting the agri-environmental issues of CAP, that they want to address, and what are the specific options in discussion.

With this information at our disposal, it will be possible to engage in completing the pre-lists of indicators to address *ex ante* policy analysis. Concretely, these pre-lists have to be organized for each pillar, that correspond to the themes of the three Activities 2.2.2 to 2.2.4. In each of them, a list of indicator candidates corresponding to the policy within the agricultural system and a list corresponding to the policy contribution to SD, have to be constructed. This can mean choosing indicators that point to differences between policy options to fulfil properties. Clearly, many indicators will be fit for diverse policies, and perhaps even for *ex ante* and *ex post* analysis at the same time, so the work is mainly to identify for each candidate indicator the various places and ways it can be used.

This information should figure on a synthetic record of indicator templates and/or fact sheets:

- Description and sources
- Its use in literature and in precedent SDI initiatives (see Appendices 1),
- Its spatial and time scales, its original unit and its ranges of variation,
- The main variables and sub-indicators susceptible to influence its contribution to SD, and the main variables and sub-indicators it is susceptible to influence. Wether the choice of this indicator for one property implies to choose a particular indicator for another property should be mentioned,
- In general and also for each relevant policy field:
    - *ex post* or *ex ante*

- properties it can represent and ranking among other candidates (for each property)
- nature of participation to the properties: P/S/R, threshold, sign, …
- the nature of its a priori contribution to sustainable development
- the eventual thresholds and target values

A database will collect all the indicators templates and fact sheets. According to the user choice concerning scale, policy field and ex post or ex ante analysis, he or she will be proposed a table analogue to Figure 4, proposing for each property the best indicator (following the ranking made). The user will be able to modify the proposed indicator by choosing in a provided list of appropriate candidates (also ranked).

Supposing one indicator per property is used, if this indicator is simple (not aggregating other indicators) then the corresponding template/fact sheet is directly presented to the user. If the indicator is composite then the information given to the user has to indicate how and why simple indicators are aggragated, i.e the aggregation scheme for this property, and direct to the templates/fact sheets of these simple indicators.

The possibility of using more than one indicator by property and weighting questions will be treated in task 2.6.

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Glossary

Dimension	The three dimensions of sustainable development : economy, social, and environment. Sometimes a fourth institutional dimension (see PD 1.2.1)
Orientor	categories of concern for the system to deal with its environment's properties. Example: adaptation orientor corresponding to environmental change. Orientor is the name given in Bossel (1999, 2002) to systemic property. (see PD 1.2.1)
Pillar	Equivalent to dimension.
Post-model analysis	The domain Post-Model Analysis includes advanced analysis in the form of sensitivity and uncertainty analysis; Synthesis and evaluation of indicators (this will include aggregation, weighing and rating etc. of indicators, multi-criteria analysis etc.) (see PD 1.1.2)
Sub-indicator	Indicator (or variable) of lesser scope and level used to build an aggregated indicator.
System Environment	An environment is a complex of external factors that acts on a system and determines its course and form of existence. An environment may be thought of as a superset, of which the given system is a subset. An environment may have one or more parameters, physical or otherwise. The environment of a given system must necessarily interact with that system (see PD 5.3.1).
Total system	At a given scale, the agricultural system is a sub-system of society as a whole, which constitutes the total system.
Systemic property	qualities of a system that it needs to maintain existence and performance within an environment.

Appendices

1 Some methodological aspects of composite indicators

Standardization

Technically, composite indicators generally imply standardizing the different sub-indicators in order to proceed to their aggregation through formal methods. The essential reason why it may be necessary to scale variables is that raw data have significantly different ranges. Salzmann (2003) identifies 4 possible techniques: 1) no standardization, 2) normalization, 3) Z-Score or Gaussian normalization[9], 4) linear scaling, where ordinal ranking and LST are subsumed in the category of linear scaling.

No standardization is satisfactory when variables are expressed in the same form, such as ratios or percentages, which is the case of HPI (Human Poverty Index, UNDP), Booysen 2002.

Normalization to a reference value for a given year is widely used and allows to put into perspective changes in percentages with time for each variable. Still, percentage appreciation between variables can be very unequal.

Gaussian normalization transforms variables so they all have a 0 mean and standard deviation of 1.

Ordinal response is the technique where experts or evaluators interpret variables and classify them according to ordinal scales, usually between 1 and 5 or 10.

Linear Scaling Technique (LST) is a technique used to standardize the range of a variable. To do this, an estimate is made for the high and low values which represent the possible range of a variable for all time periods and for all countries, and denoted Min and Max, respectively. Two main cases are used for a value V: (V-Min)/(Max-Min) or (Max-V)/ (Max-Min). In both cases the range is 0-1, but the situation of reference changes.

Aggregation

Different techniques of aggregation are used : standard averaging is straightforward, multiplicative aggregation and the use of power-averaging will be developed.

Multiplicative aggregation

Developers of an index of social or economic well-being may want to include a variable quantity such as risk, that is a conditional probability and cannot be directly measured by a single variable alone. For example, the Index of Economic Market Well-Being seeks to measure the risk of single parent poverty. The only available variables are poverty incidence of single parent families and the rate of divorce. In order to find the rate of single parent poverty, we need to consider conditional probabilities. That is, the probability of being a single parent in poverty is modelled as the probability of being in poverty if you are divorced, times the probability of being divorced2. For this reason, the index measures the rate single parent poverty as the product of the rate of divorce times the rate of poverty among single parents.

Additive Averaging

Additive averaging is a technique for aggregating variables that gives explicit weights to each variable

[9] The Z-score is calculated subtracting the mean of a data set and then dividing by its standard deviation. The technique is based on the class of functions called Gaussian curves.

and sums the product of each variable by its weight.

Power Averaging

In the power averaging method, variables, for example x, y and z, are aggregated according to $(1/3(x^{\alpha}+y^{\alpha}+z^{\alpha}))^{1/\alpha}$ This means that first, each variable is raised to the alpha power, then the terms are added and multiplied by 1/3 and then the alphath root is taken. One reason to take the alphath root after the variables are raised to the £\ power and averaged is that if all variables which are averaged have the same value, then power averaging will give exactly the same result as simple additive averaging. Anand and Sen4 (HDR: 1997) give a rigorous analysis of the technique of power-averaging without specifying alpha. Their discussion is structured by qualitatively proscribing several properties that a human poverty index should have, and showing that the mathematical formula is consistent with this.

EXPLICIT WEIGHTING OF VARIABLES

In the above methods of additive averaging and power-averaging, explicit weights must be chosen. In the discussion of power-averaging above, the choice of equal weights was made implicitly by dividing by the total number of variables. However, other weights can also be chosen. Booysen (2002) identifies widely accepted techniques : They can be set by Expert, or societal determination, by Principal Component Analysis, factor analysis or linear model regression, or by another mechanism, such as equal weighting.

Principal component analysis can be used to describe the variation of a data set using a smaller number of dimensions than number of variables of the original data. The weights of the components in the first principal component, which we call the principal component, are assigned to maximize the variation in the linear combination of original variables, or (equivalently) to maximize the sum of the squared correlations of the principal component with the original variable. PCA can be used to set weights in a set of data by using the coefficients of the first principal component as weights. Although correlation PCA has some mathematical sophistication, its use in weighting components of social indices is dubious; it is also the case for factor analysis and linear regression model of sub-indicator correlation analysis.

Other mechanisms

Equal Weighting

In light of the difficulties surrounding the explicit third party determination of weights, as well as the lack of interpretive meaning for PCA, we should consider turning our attention to the idea that all variables should a priori be weighted equally. Such a choice has to be made during the framework building, especially before choosing the list of sub-indicators. A motivation for this approach is that it is objective in the sense that if adopted as a common technique of index aggregation, the subjective component of indices aggregation would lie exclusively in the choice of variables. There is an advantage to this approach: namely, that a debate over the inclusion of variables, that is, which variables are important, can be conducted on a more basic level than a discussion that centers around the choice of numerical weights.

Opposing this point of view, Sen 1999 and Méda 1999 think that the weights of the variables that compose the indicator, just as the choice of what are the variables "that count", must be a public debate issue and must reflect the model of development a country or a community wants to pursue. Munda and Nardo 2003 point out for their part the risk of using endogenious procedures for weight choice that call for linear programming methods.

Neutralization of correlation effect

The first step of the method is to standardize the sub-indicators by subtracting the mean and dividing by the standard deviation. The standardized indices are marked as *X1*, *X2* (the correlated ones) and *Y*. A sub-index *X* is computed as an average of the *X1* and *X2*, by

$$X=[2(1+r)]^{-1/2} (X_1+X_2)$$

where *r* is the correlation coefficient between *X1* and *X2*. The sub-index *X* and the indicator *Y* are

finally combined into a composite indicator via:

$$Z= [2(1+r)]^{-1/2} (X+Y)$$

where r is the correlation coefficient between *X* and *Y*.

Distance to targets

One way to avoid explicit selection of weights is to measure the need for political intervention and the « urgency » of a problem described by the indicator, by the distance to target approach (Saisana and Tarantola 2002). Targets are expressed (by experts) in the same units as the corresponding variables, so aggregation can be done by adding the dimensionless ratios of the distance to the target by the target. An expected advantage is that indicators are linked to enforceable policies.

However, the process necessarily includes implicit weighting of urgencies, proper to each described phenomena and also relatively to sustainable development (this can be done in defining the targets, or in defining the distance to objective and independent targets). Moreover, supposing distances comparably important to SD are managed, using the target value to get dimensionless values is unsure.

Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) was proposed by Thomas Saaty in the 1970s and is a widely used technique for multi-attribute decision making. The core of AHP is an ordinal pair-wise comparison of attributes, sub-indicators in this context, in which preference statements are addressed. For a given objective, the comparisons are made per pairs of sub-indicators by firstly posing the question « Which of the two is the more important? » and secondly « By how much? ». The strength of preference is expressed on an asemantic scale of 1-9, which keeps measurement within the same order of magnitude. After, the relative weights of the sub-indicators are calculated using an eigenvector technique.

Axiomatic approach

Social choice theory proposes numerous voting procedure to elicit social preference. For instance, Munda et Nardo 2003 propose, starting from an axiomatic approach, an aggregation procedure based on a non-compensatory frame and verifying certain desired properties (adapted from Arrow and Raynaud 1986). Their procedure only calls for ranking by pair each country's performance, and not necessarily for cardinal information on the sub-indicators as AHP does. In addition to the complexity of implementing this type of procedure, two problems emerge: final ranking gives little information on the respective importance of sub-indicators in a country's performance concerning Sustainable development, and two rankings calculated at different periods do not tell if a country, having gone backwards or forward in the final ranking, owes it to the evolution of its own performances or to other country performances.

2 Main lists of sustainable development indicators

This appendices is a common tool to have in a single document all the lists of indicators of major global SDI initiatives and sectorial (agriculture) SDI comment. For each institution, the lists are presented in chronological order. Comments on each list will be done in future work.

2.1 Global initiatives

2.1.1 UN

2.1.1.1 UN Working list of SDI (1996)

Category	Driving Force Indicators	State Indicators	Response Indicators
ENVIRON-MENTAL Water	• Annual withdrawals of ground and surface water as % of available water • Domestic consumption of water per capita (m3) • Population growth in coastal areas • Discharges of oil into coastal waters (t) • Releases of nitrogen and phosphorus to coastal waters (t)	• Groundwater reserves (m3) • concentrations of faecal coliform in freshwater bodies (#/100 ml) • BOD in water bodies (mg/l) • Ratio between maximum sustained yield abundance and actual average abundance • Deviation in stock of marine species from maximum sus- tained yield level (MSY) % • Ratio between MSY abundance and actual average abundance • Algae index	• Wastewater treatment coverage (% of population served, total and by type of treatment) • Density of hydrological networks
Land	• Land use change (km2) • Population living below poverty line in dryland areas • Population dynamics in mountain areas • Use of agricultural pesticides (t/km2) • Use of fertilizers (t/km2) • Irrigation % of arable land • Energy use in agriculture	• Land condition change • National annual rainfall index • Satellite derived vegetation index • Land affected by desertification (km2)/ desertification index • Assessment of the condition and sustainable use of natural resources in mountain areas • Welfare of mountain populations • Arable land per capita • Area affected by salinization and waterlogging	• Decentralized local-level natural resource management • Agricultural education and extension • Agricultural research intensity ratio
Other Natural Resources	• Wood harvesting intensity	• Forest area change (km2) • Threatened species as % of total native species extinct #)	• Managed forest area ratio • Protected forest area as % of total land area • Protected area as % of total land area

			• R&D expenditure in the area of biotechnology • Existence of national biosafety regulations or guidelines
Atmosphere	• Emissions of greenhouse gases (t) • Emissions of sulphur oxides(t) • Emissions of nitrogen oxides (t) • Consumption of ozone depleting substances (t)	• Ambient concentrations of pollutants in urban areas (ppm)	• Expenditure on air pollution abatement (US $)
Waste	• Generation of in-dustrial and municipal solid waste (t) • Household waste disposal per capita • Generation of hazardous wastes (t) • Imports and exports of hazardous waste (t)	• Chemically induced acute poisonings • Area of land contaminated by hazardous wastes (km2)	• Expenditure on waste management (US$) • Rate of waste recycling, reuse • Municipal waste disposal (t/capita) • Number of chemicals banned or severely restricted • Expenditure on hazardous waste treatment
SOCIAL	• Unemployment rate • Population growth rate • Net migration rate • Total fertility rate • Rate of change of school-age population • Primary school enrollment ratio (gross and net) • Adult literacy rate • Rate of growth of urban population • Per capital consumption of fossil fuel by motor vehicle transport • Human and economic loss due to natural disasters	• Measures of poverty • Ratio of average female wage to male wage • Population density • Children reaching grade 5 of primary education • School life expectancy • Difference between male and female school enrollment ratios • Women per hundred men in the labor force • Basic sanitation: % of population with adequate excreta disposal facilities • % people with safe drinking water available in home or with reasonable access • Life expectancy at birth • Adequate birth weight • Infant mortality rate • Maternal mortality rate • Nutritional status of children • % of population in urban areas • Area and population of urban formal and informal settlements • Floor area per person • House price to income	• GDP spent on education • % eligible population that have been immunized according to national immunization policies • Contraceptive prevalence • Proportion of potentially hazardous chemicals monitored in food; • National health expenditure devoted to local health care • Total national health expenditure related to GNP • Infrastructure expenditure per capita

		ratio	
ECONOMIC	• GDP per capita • Net investment share in GDP • Sum of exports and imports as a percent of GDP • Annual energy consumption per capita • Share of natural resource intensive industries in manufacturing value added • Net resources transfer/GNP • Total ODA given or received as a percentage of GNP • Capital good imports • Foreign direct investments	• Environmentally adjusted Net Domestic Product per capita • Share of manufactured goods in total merchandise exports • Proven mineral reserves • Proven fossil fuel energy reserves • Lifetime of proven energy reserves • Intensity of material use • Share of manufacturing value-added GDP • Share of consumption of renewable energy resources • Debt/GNP • Debt service/export • Share of environmentally sound capital goods imports in total capital goods imports	• Environmental protection expenditures as a percent of GDP • Amount of new or additional funding for sustainable development • Technical cooperation grants

2.1.1.2 UN Key Themes (2001)

Social	Environmental
Education	Freshwater/groundwater
Employment	Agriculture/secure food supply
Health/water supply/sanitation	Urban
Housing	Coastal Zone
Welfare and quality of life	Marine environment/coral reef protection
Cultural heritage	Fisheries
Poverty/Income distribution	Biodiversity/biotechnology
Crime	Sustainable forest management
Population	Air pollution and ozone depletion
Social and ethical values	Global climate change/sea level rise
Role of women	Sustainable use of natural resources
Access to land and resources	Sustainable tourism
Community structure	Restricted carrying capacity
Equity/social exclusion	Land use change
Economic	**Institutional**
Economic dependency/Indebtedness/ODA	Integrated decision-making
Energy	Capacity building
Consumption and production patterns	Science and technology
Waste management	Public awareness and information
Transportation	International conventions and cooperation
Mining	Governance/role of civic society
Economic structure and development	Institutional and legislative frameworks
Trade	Disaster preparedness
Productivity	Public participation

2.1.1.3 UN Core indicators (2001)

SOCIAL					
Theme	**Sub-theme**	**Indicator**	**DF**	**S**	**R**
Equity	Poverty	Percent of Population Living below the Poverty Line		X	
		Gini Index of Income Inequality		X	
		Unemployment Rate	X		
	Gender Equality	Ratio of Average Female Wage to Male Wage		X	
Health	Nutrition Status	Nutritional Status of Children		X	
	Mortality	Mortality Rate Under 5 Years Old		X	
		Life Expectancy at Birth		X	
	Sanitation	Percent of Population with Adequate Sewage Disposal Facilities		X	
	Drinking Water	Population with Access to Safe Drinking Water		X	
	Healthcare Delivery	Percent of Population with Access to Primary Health Care Facilities			X
		Immunization Against Infectious Childhood Diseases			X
		Contraceptive Prevalence Rate			X
Education	Education Level	Children Reaching Grade 5 of Primary Education	X		
		Adult Secondary Education Achievement Level	X		
	Literacy	Adult Literacy Rate	X		
Housing	Living Conditions	Floor Area per Person		X	
Security	Crime	Number of Recorded Crimes per 100,000 Population		X	
Population	Population Change	Population Growth Rate	X		
		Population of Urban Formal and Informal Settlements		X	
ENVIRONMENTAL					
Theme	**Sub-theme**	**Indicator**	**DF**	**S**	**R**
Atmosphere	Climate Change	Emissions of Greenhouse Gases	X		
	Ozone Layer Depletion	Consumption of Ozone Depleting Substances	X		
	Air Quality	Ambient Concentration of Air Pollutants in Urban Areas		X	
Land	Agriculture	Arable and Permanent Crop Land Area		X	
		Use of Fertilizers	X		
		Use of Agricultural Pesticides	X		
	Forests	Forest Area as a Percent of Land Area		X	
		Wood Harvesting Intensity	X		
	Desertification	Land Affected by Desertification		X	
	Urbanization	Area of Urban Formal and Informal Settlements		X	
Oceans, Seas and Coasts	Coastal Zone	Algae Concentration in Coastal Waters		X	
		Percent of Total Population Living in Coastal Areas	X		
	Fisheries	Annual Catch by Major Species	X		

ENVIRONMENTAL					
Theme	**Sub-theme**	**Indicator**	**DF**	**S**	**R**
Fresh Water	Water Quantity	Annual Withdrawal of Ground and Surface Water as a Percent of Total Available Water	X		
	Water Quality	BOD in Water Bodies		X	
		Concentration of Faecal Coliform in Freshwater		X	
Biodiversity	Ecosystem	Area of Selected Key Ecosystems		X	
		Protected Area as a Percent of Total Area			X
	Species	Abundance of Selected Key Species		X	
ECONOMIC					
Theme	**Sub-theme**	**Indicator**	**DF**	**S**	**R**
Economic Structure	Economic Performance	GDP per Capita	X		
		Investment Share in GDP	X		
	Trade	Balance of Trade in Goods and Services		X	
	Financial Status	Debt to GNP Ratio		X	
		Total ODA Given or Received as a Percent of GNP	X		
Consumption and Production Patterns	Material Consumption	Intensity of Material Use		X	
	Energy Use	Annual Energy Consumption per Capita	X		
		Share of Consumption of Renewable Energy Resources		X	
		Intensity of Energy use		X	
	Waste Generation and Management	Generation of Industrial and Municipal Solid Waste	X		
		Generation of Hazardous Waste	X		
		Generation of Radioactive Waste	X		
		Waste Recycling and Reuse			X
	Transportation	Distance Traveled per Capita by Mode of Transport		X	
INSTITUTIONAL					
Theme	**Sub-theme**	**Indicator**	**DF**	**S**	**R**
Institutional Framework	Strategic Implementation of SD	National Sustainable Development Strategy			X
	International Cooperation	Implementation of Ratified Global Agreements			X
Institutional Capacity	Information Access	Number of Internet Subscribers per 1000 Population		X	
	Communication Infrastructure	Main Telephone Lines per 1000 Population		X	
	Science and Technology	Expenditure on Research and Development as a % of GDP			X
	Disaster Preparedness and Response	Economic and Human Loss Due to Natural Disasters	X		

2.1.2 European Union

2.1.2.1 Eurostat list of SDI

Table 1. Themes

ECONOMIC DEVELOPMENT
POVERTY and SOCIAL EXCLUSION
AGEING SOCIETY
PUBLIC HEALTH
CLIMATE CHANGE AND ENERGY
PRODUCTION and CONSUMPTION PATTERNS
MANAGEMENT of NATURAL RESOURCES
TRANSPORT and LAND USE MANAGEMENT
GOOD GOVERNANCE
GLOBAL PARTNERSHIP

Level I	Sub-themes	Level II	Level III	Headline Objectives in the EU SD Strategy (SDS) Presidency conclusions of European Council (EC) WSSD Plan of Implementation (PoI) 6th Environmental Action Programme (6EAP) Millenium Declaration Goals
THEME 1: ECONOMIC DEVELOPMENT				
1. Growth rate of GDP per capita	INVESTMENT	1. Investment as % of GDP, by institutional sector	1. Real GDP growth rate 2. GDP per capita in Purchasing Power Standards 3. Regional breakdown of GDP per capita 4. Total consumption expenditure as % of GDP 5. Net national income as a % of GDP 6. Inflation rate 7. Net saving as % of GDP, by institutional sector	EC Lisbon2000: An average economic growth rate of around 3% a realistic prospect for the coming years. The inflation rate of a given Member State must not exceed by more than 1½ percentage points that of the three best-performing Member States in terms of price stability. SDS: Promote more balanced regional development by reducing disparities in economic activity and maintaining the viability of rural and urban communities, as recommended by the European Spatial Development Perspective
	COMPETITIVENESS	2. Labour productivity per hour worked 3. International price competitiveness (Real effective exchange rate)	8. Unit labour cost growth, for total and industry 9. Life-long learning 10. Turnover from innovation as a % of total turnover, by economic sector 11. Total R&D expenditure as a % of GDP 12. Public expenditure on education as a % of GDP	EC Lisbon2000: A substantial annual increase in per capita investment in human resources. Provide new basic skills through lifelong learning of IT skills, foreign languages, technological culture, entrepreneurship and social skills. EC Barcelona 2002: Increase spending of R&D and innovation with the aim of approaching 3% of GDP by 2010.
	EMPLOYMENT	4. Total employment rate	13. Total employment growth 14. Total employment rate, by gender and by highest level of education attained 15. Total unemployment rate, by gender, by age group, and by highest level of education attained 16. Regional breakdown of employment rate	EC Lisbon2000, SDS: Raise the employment rate to 67% for January 2005 and to 70% by 2010; increase the number of women in employment to 57% for January 2005 and to more than 60% by 2010.
THEME 2: POVERTY and SOCIAL EXCLUSION				
1. At-risk-of-poverty rate after social transfers	MONETARY POVERTY	1. At-persistent-risk-of-poverty rate	1. At-risk-of-poverty rate, by gender, by age group, by highest level of education attained, and by household type 2. Relative at-risk-of-poverty gap 3. Inequality of income distribution (Income quintile share ratio) *4. Poverty mobility (i.e. probability to enter or exit poverty)*	EC Lisbon2000, SDS: Make a decisive impact on the eradication of poverty; greater social cohesion EC Barcelona2002: Reduce significantly the number of person at risk of poverty and social exclusion by 2010 GP 2002: Ensure adequate financing to attain the International Development Targets and the MDGs
	ACCESS TO LABOURMARKET	2. Total long-term unemployment rate	5. Gender pay gap in unadjusted form 6. Very long-term unemployment rate 7. People living in jobless households, by age group 8. At risk-of-poverty rate after social transfers by most frequent activity	EC Lisbon2000: sustainable economic growth with more and better jobs
	OTHER ASPECTS OF SOCIAL EXCLUSION	3. Early school leavers	9. Persons with low educational attainment, by age group *10. Adequacy of housing conditions*	EC Lisbon2000, SDS: Halve by 2010 the number of 18 to 24 years olds with only lower secondary education who are not in further education and training GP 2002: Ensure adequate financing to attain the International Development Targets and the MDGs

Level I	Sub-themes	Level II	Level III	Headline Objectives in the EU SD Strategy (SDS) Presidency conclusions of European Council (EC) WSSD Plan of Implementation (PoI) 6th Environmental Action Programme (6EAP) Millenium Declaration Goals
THEME 3: AGEING SOCIETY				
1. Current and projected old age dependency ratio	PENSIONS ADEQUACY	*1. Projected theoretical replacement ratio (ratio between income after and prior to retirement)* 1a. Ratio of median household equivalised income of persons aged 65+ to median household equivalised income of persons aged <65	1. At-risk-of-poverty rate for persons aged 65 years and over	SDS: Address the demographic challenge by raising employment rates, reducing public debt and adapting social protection systems, including pension systems. SDS: Ensure the adequacy of pension systems as well as of health care systems and care of the elderly, while at the same time maintaining sustainability of public finances and inter-generational solidarity. SDS: Increase the average EU employment rate among older women and men (55-64) to 50% by 2010. EC Barcelona 2002: A progressive increase of about 5 years in the effective average age at which people stop working in the EU should be sought by 2010. EC Cardiff1998: Public sector budgetary deficit to be less than 3% of GDP and gross debt less than 60% of GDP.
	DEMOGRAPHIC CHANGES	2. Life expectancy at age 65 by gender	2. Total fertility rate 3. Net inwards migration, by main age groups	
	PUBLIC FINANCE SUSTAINABILITY	3. General government consolidated gross debt as % of GDP	4. Current *and projected* public *(and private)* pensions expenditure as % of GDP 5. Total employment rate by age group 6. Average exit age from the labour market 7. Current *and projected* public expenditure on care for the elderly as % of GDP	
THEME 4: PUBLIC HEALTH				
1. Healthy life years at birth by gender	HUMAN HEALTH PROTECTION AND LIFESTYLES	1. Percentage of overweight people, *by age group* 2. Resistance to antibiotics (Streptococcus pneumoniae pathogens)	1. Healthy life years at age 65 by gender 2. Health care expenditure as % of GDP 3. Cancer incidence rate, by gender and by type 4. Suicide death rate, by gender and by age group 5. Percentage of present smokers, by gender and by age group *6. Work with high level of job strain/stress* 7. Serious accidents at work	SDS: Ensure the adequacy of pension systems as well as of health care systems and care of the elderly, while at the same time maintaining sustainability of public finances and inter-generational solidarity. SDS: Tackle issues related to outbreaks of infectious diseases and resistance to antibiotics. PoI2002: Enhance health education with the objective of achieving improved health literacy on a global basis by 2010.
	FOOD SAFETY AND QUALITY	*3. Deaths due to infectious food-borne diseases* 3a. Salmonellosis incidence rate in human beings	*8. Dioxins and PCBs in food and feed* *9. Heavy metals, and mercury in particular, in fish and shellfish* *10. Pesticides residues in food*	SDS: Make food safety and quality the objective of all players in the food chain. 6EAP: Reduce impacts of pesticides on human health and environment; achieve a more sustainable use of pesticides, a significant overall reduction in risks and use of pesticides consistent with the necessary crop production.
	CHEMICALS MANAGEMNT	*4. Index of apparent consumption of chemicals, by toxicity class* 4a. Index of production of chemicals, by toxicity class		SDS: By 2020, ensure that chemicals are only produced and used in ways that do not pose significant threats to human health and the environment. 6EAP: Dangerous chemicals (especially PBTs) should be substituted with the aim of reducing risks to man and the environment (ground and surface water, air quality).
	HEALTH RISKS DUE TO ENVIRONMENT. CONDITIONS	*5. Population exposure to air pollution by particulate matter*	*11. Population exposure to air pollution by ozone* 12. Proportion of population living in households considering that they suffer from noise and from pollution *13. Monetary damage of air pollution as % of GDP*	6EAP: Achieving levels of air quality that do not give rise to significant negative impacts on and risks to human health and the environment. 6EAP: Substantially reducing the number of people regularly affected by long-term average levels of noise.

Level I	Sub-themes	Level II	Level III	Headline Objectives in the EU SD Strategy (SDS) Presidency conclusions of European Council (EC) WSSD Plan of Implementation (PoI) 6th Environmental Action Programme (6EAP) Millenium Declaration Goals
THEME 6: PRODUCTION AND CONSUMPTION PATTERNS				
1. *Total material consumption and GDP at constant prices*	ECO-EFFICIENCY	1. Emissions of acidifying substances and ozone precursors and GDP at constant prices, by source sector 2. *Generation of waste by all economic activities and by households* 2a. Municipal waste collected per capita	1. Components of Domestic Material Consumption 2. Domestic Material Consumption, by material 3. Municipal waste treatment, by type of treatment method 4. *Generation of hazardous waste, by economic activity*	SDS: Break the links between economic growth, use of resources and generation of waste. Propose system of a resource productivity measurement to be operational by 2003. 6EAP: Achieve a significant overall reduction in the volumes of waste & hazardous waste generated and going to disposal, without increasing emissions to air, water and soil. PoI2002: Promote the development of 10-year framework of programs to accelerate the shifts towards sustainable consumption and production. Renew commitments to the sound management of chemicals & hazardous wastes throughout their life-cycle.
1a. Domestic Material Consumption and GDP at constant prices	CONSUMPTION PATTERNS	3. Electricity consumption per dwelling for lighting and domestic appliances 4. *Green public procurement*	5. Household number and size 6. Meat consumption per capita 7. *Share of consumption of products with an EU or national eco-label*	SDS: Institutional reform and changes in corporate and consumer behaviour. Encourage private sector initiatives to incorporate environmental factors in their purchasing specifications. PoI2002: Develop and adopt effective, transparent, verifiable, non-misleading and non-discriminatory consumer information tools to provide information relating to sustainable consumption and production, including human health and safety aspects.
	AGRI-CULTURE	5. Share of area under EU agri-environmental support in total utilised agricultural area 6. Livestock density index	8. Nitrogen surplus 9. Share of area occupied by organic farming in total utilised agricultural area 10. *Use of selected pesticides*	SDS: The CAP should contribute to achieving sustainable development by encouraging healthy, high quality products, environmentally sustainable production methods, including organic production, renewable raw materials and the protection of biodiversity.
	CORPORATE RESPONSIBILITY	7. *Share of industrial production from enterprises with a formal sustainable management system* 7a. Enterprises with an environmental management system (EMS)	11. *Ethical financing* 12. Eco-label awards, by country and by product group	SDS: Publish annually a triple bottom line measuring companies' performance against economic, environmental and social criteria. Demonstrate and publicize worldwide adherence of EU businesses to the OECD guidelines for multi-national enterprises or other comparable guidelines. EC Lisbon2000: An appeal to companies' sense of social responsibility regarding best practices in lifelong learning, work organization, equal opportunities, social inclusion and sustainable development. PoI2002: Promote corporate responsibility & accountability, incl. through development and implementation of intergovernmental agreements & measures, international initiatives, public-private partnerships, and national regulations.

Level I	Sub-themes	Level II	Level III	Headline Objectives in the EU SD Strategy (SDS) Presidency conclusions of European Council (EC) WSSD Plan of Implementation (PoI) 6th Environmental Action Programme (6EAP) Millenium Declaration Goals
THEME 7: MANAGEMENT OF NATURAL RESOURCES				
1. *Biodiversity Index* 1a. Population trends of farmland birds 2. Fish catches outside safe biological limits	BIODIVERSITY	1. *Sufficiency of Member States proposals for protected sites under the EU Habitats directive*	1. *Change in status of threatened and/or protected species*	SDS: Protect and restore habitats and natural systems and halt the loss of biodiversity by 2010. 6EAP: Conservation of species and habitats with a special concern of preventing habitat fragmentation. Ensure that the consumption of resources and their associated impacts do not exceed the carrying capacity of the environment. GP 2002: Ensure adequate financing to attain the International Development Targets and the MDGs
	MARINE ECOSYSTEMS	2. *Trends of spawning biomass of selected fish stocks*	2. *Effective fishing capacity and quotas, by specific fisheries* 2a. Size of fishing fleet 3. *Structural support to fisheries and % allocated to promote env. friendly fishing practices*	EC Gothenburg2001: The review of the CFP should address the overall fishing pressure by adapting the EU fishing effort to the level of available resources, taking into account the social impact and the need to avoid over-fishing. 6EAP: Conservation, appropriate restoration and sustainable use of marine environment, coasts and wetlands. PoI2002: On an urgent basis, and where possible by 2015, maintain or restore depleted fish stocks to levels that can produce the maximum sustainable yield.
	FRESH WATER RESOURCES	3. Groundwater abstraction as % of available groundwater resources	4. Population connected to wastewater treatment systems 5. *Emissions of organic matter as biochemical oxygen demand to rivers* 6. *Index of toxic chemical risk to aquatic environment*	6EAP: Ensure that the rates of extraction from water resources are sustainable over the long term. Achieve quality levels of ground and surface water that do not give rise to significant impacts on and risks to human health and the environment. PoI2002: Develop integrated water resources management and water-efficiency plans by 2005. GP 2002: Ensure adequate financing to attain the International Development Targets and the MDGs
	LAND USE	4. *Land use change, by category* 4a. Built-up area as a % of total land area 5. *Exceedance of critical loads of acidifying substances and nitrogen in sensitive natural areas*	7. *Percentage of total land area at risk of soil erosion* 8. *Percentage of total land area at risk of soil contamination* 9. Percentage of forest trees damaged by defoliation 10. *Fragmentation of habitats due to transport*	6EAP: Conserve and restore areas of significant landscape value including cultivated and sensitive areas. Promotion of sustainable use of the soil, with particular attention to preventing erosion, deterioration, contamination and desertification. PoI2002: Accelerate the implementation of the IPF/IFF proposals for action and by the Collaborative Partnership on Forests, and intensify efforts on reporting to the UN Forum of Forests so as to contribute to an assessment of progress in 2005.

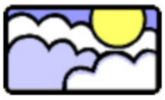
<table>
<tr><th>Level I</th><th>Sub-themes</th><th>Level II</th><th>Level III</th><th>Headline Objectives in the EU SD Strategy (SDS)
Presidency conclusions of European Council (EC)
WSSD Plan of Implementation (PoI)
6th Environmental Action Programme (6EAP)
Millenium Declaration Goals</th></tr>
<tr><td colspan="5">THEME 8: TRANSPORT</td></tr>
<tr><td rowspan="3">1. Vehicle-km and GDP at constant price
1a. Energy consumption by transport and GDP at constant price</td><td>TRANSPORT GROWTH</td><td>1. Car share of inland passenger transport
2. Road share of inland freight transport</td><td>1. Modal split of passenger transport
2. Modal split of freight transport
3. Volume of freight transport and GDP at constant price
4. Energy consumption by transport mode
5. Access to public transport</td><td rowspan="3">SDS: Decouple transport growth significantly from growth in Gross Domestic Product in order to reduce congestion and other negative side effects of transport.
SDS: Bring about a shift in transport use from road to rail, water and public passenger transport so that the share of road transport in 2010 is no greater than in 1998. Promote teleworking.
(Updated in EC Gothenburg2001): The sustainable transport policy should tackle rising levels of congestion, noise and pollution and encourage use of more environmentally - friendly modes of transport as well as the full internalisation of social and environmental costs. Propose a framework for transport charges to ensure that by 2004 prices for different modes of transport, including air, reflect their costs to society.</td></tr>
<tr><td>TRANSPORT PRICES</td><td>3. External costs of transport activities</td><td>6. Freight transport prices by mode
7. Investment in transport infrastructure by mode</td></tr>
<tr><td>SOCIAL AND ENVIRONMENTAL IMPACT OF TRANSPORT</td><td>4. Emissions of air pollutants (particulate matter and ozone precursors) from transport activities
5. Greenhouse gas emissions by transport activities, by mode</td><td>8. People killed in road accidents, by age group
9. Emissions of NO_x from road vehicles (petrol and diesel)</td></tr>
<tr><td colspan="5">THEME 9: GOOD GOVERNANCE</td></tr>
<tr><td rowspan="2">1. Level of citizens' confidence in EU institutions</td><td>POLICY COHERENCE</td><td>1. Proportion of environmentally harmful subsidies
2. Number of infringement cases brought in front of the Court of Justice, by policy area
3. Administrative cost imposed by legislation</td><td>1. Share of major proposals in the Commission's Legal and Work Programme for which an impact assessment has been undertaken
2. Transposition of Community law, by policy area</td><td rowspan="2">SDS: Improve policy coherence; all policies must have sustainable development as their core concern. In particular, forthcoming reviews of Common Policies must look at how they can contribute more positively to sustainable development.
(revised in Barcelone2002): Ensure that all major internal and external policy proposals include an impact assessment.
SDS: Earlier and more systematic dialogue, in particular with representatives of consumers. The views outside the Union should also be sought.
EC Lisbon2000: Real efforts must be made by public administrations at all levels to exploit new technologies to make information as accessible as possible.
EC Gothenburg2001: The Union must be served by modern, open and citizen-oriented institutions. The new rules on the public's right of access to documents are a major step in making the Union more open.</td></tr>
<tr><td>PUBLIC PARTICIPATION</td><td>4. Voter turnout in national parliamentary elections
5. Responses to EC Internet public consultations</td><td>3. Voter turnout in EU parliamentary elections, by gender, by age group and by highest level of education attained
4. E-government on-line availability
5. E-government usage by individuals</td></tr>
</table>

2.1.2.2 EEA list of Environmental indicators

Agriculture Area under organic farming (CSI 026) Gross nutrient balance (CSI 025)	**Fisheries** Aquaculture production (CSI 033) Fishing fleet capacity (CSI 034) Status of marine fish stocks (CSI 032)
Air pollution and ozone depletion Consumption of ozone depleting substances (CSI 006) Emissions of acidifying substances (CSI 001) Emissions of ozone precursors (CSI 002) Emissions of primary particulates and secondary particulate precursors (CSI 003) Exceedance of air quality limit values in urban areas (CSI 004) Exposure of ecosystems to acidification, eutrophication and ozone (CSI 005)	**Terrestrial** Land take (CSI 014) Progress in management of contaminated sites (CSI 015) **Transport** Freight transport demand (CSI 036) Passenger transport demand (CSI 035) Use of cleaner and alternative fuels (CSI 037)
Biodiversity Designated areas (CSI 008) Species diversity (CSI 009) Threatened and protected species (CSI 007)	**Waste** Generation and recycling of packaging waste (CSI 017) Municipal waste generation (CSI 016)
Climate change Atmospheric greenhouse gas concentrations (CSI 013) Global and European temperature (CSI 012) Greenhouse gas emissions and removals (CSI 010) Projections of green-house gas emissions and removals and policies and measures (CSI 011)	**Water** Bathing water quality (CSI 022) Chlorophyll in transitional, coastal and marine waters (CSI 023) Nutrients in freshwater (CSI 020) Nutrients in transitional, coastal and marine waters (CSI 021) Oxygen consuming substances in rivers (CSI 019) Urban waste water treatment (CSI 024) Use of freshwater resources (CSI 018)
Energy Final energy consumption by sector (CSI 027) Renewable electricity (CSI 031) Renewable energy consumption (CSI 030) Total energy consumption by fuel (CSI 029) Total energy intensity (CSI 028)	

2.1.2.3 TEPI - Towards Environmental Pressure Indicators for the EU

These are the indicators of the third TEPI project year.

POLICY FIELD	CODE	NAME
Air Pollution	AP1	Emissions of nitrogen oxides (NOx)
	AP2	Emissions of non-methane volatile organic compounds (NMVOCs)
	AP3	Emissions of sulphur dioxide (SO2)
	AP4	Emissions of particles
	AP5	Consumption of petrol and diesel oil by road vehicles
	AP6	Primary energy consumption
Climate Change	CC1	Emissions of carbon dioxide (CO2)
	CC2	Emissions of methane (CH4)
	CC3	Emissions of nitrous oxide (N2O)
	CC4	Emissions of Hydrofluorocarbons (HFCs)
	CC5	Emissions of PerFluoroCarbons (PFCs)
	CC6	Emissions of Sulphurhexafluoride (SF6)
Loss of Biodiversity	LB1	Protected area, loss, damage and defragmentation
	LB2	Wetlands loss
	LB3	Agriculture intensity: area used for intensive arable agriculture
	LB4	Fragmentation of forests & landscapes by roads / intersections
	LB5	Forest damage
	LB6	Change in traditional land-use practice
Marine Environment & Coastal Zones	ME1	Eutrophication
	ME2	Fishing pressure
	ME3	Development along shore
	ME4	Discharges of heavy metals
	ME5	Oil pollution at coast and at sea
	ME6	Tourism intensity
Ozone Layer Depletion	OD1	Emissions of bromofluorocarbons (halons)
	OD2	Emissions of chlorofluorocarbons (CFCs)
	OD3	Emissions of hydrochlorofluorocarbons (HCFCs)
	OD4	Emissions of nitrogen oxides (NOx) by aircraft
	OD5	Emissions of chlorinated carbons
	OD6	Emissions of industrially produced methyl bromide
Resource Depletion	RD1	Water consumption
	RD2	Energy use
	RD3	Increase in territory permanently occupied by urbanisation
	RD4	Nutrient balance of the soil
	RD5	Electricity production from fossil fuels
	RD6	Timber balance
Dispersion of Toxic Substances	TX1	Consumption of pesticides by agriculture
	TX2	Emissions of persistent organic pollutants by economic activity
	TX3	Consumption of toxic chemicals
	TX4	Index of heavy metals emissions into the water
	TX5	Index of heavy metals emissions into the air
	TX6	Emissions of radioactive material
Urban Environment Problems	UP1	Urban energy consumption
	UP2	Non-recycled municipal waste

2.1.2.4 ESI list of variables

Comp-onent	Indicator Number	Indicator	Variable Number	Variable Code	Variable
Environmental Systems	1	Air Quality	1	NO2	Urban population weighted NO_2 concentration
			2	SO2	Urban population weighted SO_2 concentration
			3	TSP	Urban population weighted TSP concentration
			4	INDOOR	Indoor air pollution from solid fuel use
	2	Biodiversity	5	ECORISK	Percentage of country's territory in threatened ecoregions
			6	PRTBRD	Threatened bird species as percentage of known breeding bird species in each country
			7	PRTMAM	Threatened mammal species as percentage of known mammal species in each country
			8	PRTAMPH	Threatened amphibian species as percentage of known amphibian species in each country
			9	NBI	National Biodiversity Index
	3	Land	10	ANTH10	Percentage of total land area (including inland waters) having very low anthropogenic impact
			11	ANTH40	Percentage of total land area (including inland waters) having very high anthropogenic impact
	4	Water Quality	12	WQ_DO	Dissolved oxygen concentration
			13	WQ_EC	Electrical conductivity
			14	WQ_PH	Phosphorus concentration
			15	WQ_SS	Suspended solids
	5	Water Quantity	16	WATAVL	Freshwater availability per capita
			17	GRDAVL	Internal groundwater availability per capita
Reducing Environmental Stresses	6	Reducing Air Pollution	18	COALKM	Coal consumption per populated land area
			19	NOXKM	Anthropogenic NO_x emissions per populated land area
			20	SO2KM	Anthropogenic SO_2 emissions per populated land area
			21	VOCKM	Anthropogenic VOC emissions per populated land area
			22	CARSKM	Vehicles in use per populated land area
	7	Reducing Ecosystem Stress	23	FOREST	Annual average forest cover change rate from 1990 to 2000
			24	ACEXC	Acidification exceedance from anthropogenic sulfur deposition
	8	Reducing Population Pressure	25	GR2050	Percentage change in projected population 2004-2050
			26	TFR	Total Fertility Rate
	9	Reducing Waste & Consumption Pressures	27	EFPC	Ecological Footprint per capita
			28	RECYCLE	Waste recycling rates
			29	HAZWST	Generation of hazardous waste
	10	Reducing Water Stress	30	BODWAT	Industrial organic water pollutant (BOD) emissions per available freshwater
			31	FERTHA	Fertilizer consumption per hectare of arable land
			32	PESTHA	Pesticide consumption per hectare of arable land
			33	WATSTR	Percentage of country under severe water stress
	11	Natural Resource Management	34	OVRFSH	Productivity overfishing
			35	FORCERT	Percentage of total forest area that is certified for sustainable management
			36	WEFSUB	World Economic Forum Survey on subsidies
			37	IRRSAL	Salinized area due to irrigation as percentage of total arable land
			38	AGSUB	Agricultural subsidies

Component	Indicator Number	Indicator	Variable Number	Variable Code	Variable
Reducing Human Vulnerability	12	Environmental Health	39	DISINT	Death rate from intestinal infectious diseases
			40	DISRES	Child death rate from respiratory diseases
			41	U5MORT	Children under five mortality rate per 1,000 live births
	13	Basic Human Sustenance	42	UND_NO	Percentage of undernourished in total population
			43	WATSUP	Percentage of population with access to improved drinking water source
	14	Reducing Environment-Related Natural Disaster Vulnerability	44	DISCAS	Average number of deaths per million inhabitants from floods, tropical cyclones, and droughts
			45	DISEXP	Environmental Hazard Exposure Index
Social and Institutional Capacity	15	Environmental Governance	46	GASPR	Ratio of gasoline price to world average
			47	GRAFT	Corruption measure
			48	GOVEFF	Government effectiveness
			49	PRAREA	Percentage of total land area under protected status
			50	WEFGOV	World Economic Forum Survey on environmental governance
			51	LAW	Rule of law
			52	AGENDA21	Local Agenda 21 initiatives per million people
			53	CIVLIB	Civil and Political Liberties
			54	CSDMIS	Percentage of variables missing from the CGSDI "Rio to Joburg Dashboard"
			55	IUCN	IUCN member organizations per million population
			56	KNWLDG	Knowledge creation in environmental science, technology, and policy
			57	POLITY	Democracy measure
	16	Eco-Efficiency	58	ENEFF	Energy efficiency
			59	RENPC	Hydropower and renewable energy production as a percentage of total energy consumption
	17	Private Sector Responsiveness	60	DJSGI	Dow Jones Sustainability Group Index (DJSGI)
			61	ECOVAL	Average Innovest EcoValue rating of firms headquartered in a country
			62	ISO14	Number of ISO 14001 certified companies per billion dollars GDP (PPP)
			63	WEFPRI	World Economic Forum Survey on private sector environmental innovation
			64	RESCARE	Participation in the Responsible Care Program of the Chemical Manufacturer's Association
	18	Science and Technology	65	INNOV	Innovation Index
			66	DAI	Digital Access Index
			67	PECR	Female primary education completion rate
			68	ENROL	Gross tertiary enrollment rate
			69	RESEARCH	Number of researchers per million inhabitants
Global Stewardship	19	Participation in International Collaborative Efforts	70	EIONUM	Number of memberships in environmental intergovernmental organizations
			71	FUNDING	Contribution to international and bilateral funding of environmental projects and development aid
			72	PARTICIP	Participation in international environmental agreements
	20	Greenhouse Gas Emissions	73	CO2GDP	Carbon emissions per million US dollars GDP
			74	CO2PC	Carbon emissions per capita
	21	Reducing Transboundary Environmental Pressures	75	SO2EXP	SO_2 Exports
			76	POLEXP	Import of polluting goods and raw materials as percentage of total imports of goods and services

2.1.3 OECD

2.1.3.1 OECD A Preliminary Set of SDI (1991)

18 ENVIRONMENTAL INDICATORS	7 KEY INDICATORS
CO2 emissions Greenhouse gas emissions S0x emissions N0x emissions Use of water resources River quality Wastewater treatment Land use changes Protected areas Use of nitrogenous fertilizers Use of forest resources Trade in tropical wood Threatened species Fish catches Waste generation Municipal waste Industrial accidents Public opinion	Growth of economic activity Energy intensity Energy supply Industrial production Transport trends Private fuel consumption Population

2.1.3.2 OECD A Preliminary Set of SDI (OECD 2003)

Gaz à effet de serre	**Gestion des ressources naturelles**
Global	Consommation de ressources
Température de surface moyenne globale	Rendement constant de la pêche
Température de surface des océans	Intensité de ressources forestières
National	Prélèvements d'eau
Emissions de gaz à effet de serre (total)	Erosion des sols
Emissions de gaz à effet de serre (par unité de PIB)	Utilisation des sols
Sectoriel	
Emissions de GES - Electricité (par KWh)	**Gestion des déchets**
Emissions de GES - Industrie (par unité de production)	Ordures ménagères (totales et rapportées à la consommation)
Emissions de dioxyde de carbone - Transports (par véhicule)	Ensemble des déchets (total et rapporté au PIB)
Part des énergies renouvelables dans la production totale d'électricité	Déchets dangereux (total)
	Déchets nucléaires (total)
Pollution atmosphérique	
Concentrations de dioxyde de soufre	**Viabilité des revenus des retraites**
Emissions de soufre	Projections des dépenses de retraites publiques
Concentrations de dioxyde d'azote	Age moyen de sortie du marché du travail
Emissions de dioxyde d'azote	Proportion de salariés de plus de 55ans
Concentrations de composés organiques volatils (COV)	Comptes personnels d'épargne-retraite et avoirs des caisses de retraites publiques
Emissions de COV	
Concentrations de monoxyde de carbone	**Niveau de vie dans les pays en développement**
Emissions de monoxyde de carbone	Extrême pauvreté
Concentrations de particules	Importations des pays les moins avancés
Emissions de particules	Importations des pays à faible revenu
Particules (nombre de jours de dépassement des valeurs guides)	Concentration par pays des importations de l'OCDE
Concentrations d'ozone	Part de l'APD non liée
Ozone (nombre de jours de dépassement des valeurs guides)	APD totale
Pollution de l'eau	Participation moyenne des bénéficiaires de l'aide dans les partenariats
Demande biochimique en oxygène	Progression des revenus moyens
Concentrations de phosphates	Tarif douanier moyen
Concentrations de nitrates	Population bénéficiant d'un approvisionnement adéquat en eau dans les pays en développement
Bilan de l'azote	Part de la population bénéficiant de service d'assainissement adéquat dans les PVD
Bilan du phosphate	Mortalité infantile dans les PVD
Concentrations de cadmium	Espérance de vie dans les PVD
Concentrations de chrome	Taux d'illettrisme dans les PVD
Concentrations de plomb	
Concentrations de pesticides	

2.1.3.3 OECD CEI

"CEI are designed to help track environmental progress and the factors involved in it, and analyse environmental policies. The OECD Core Set is a set commonly agreed upon by OECD countries for OECD use. It is published regularly. The Core Set, of about 50 indicators, covers issues that reflect the main environmental concerns in OECD countries. It incorporates core indicators derived from sectoral sets and from environmental accounting. Indicators are classified following the PSR model: indicators of environmental pressures, both direct and indirect; indicators of environmental conditions; indicators of society's responses." (OECD 2005)

Issue		Core indicators[7]	([8])
Climate change	Pressures	**Index of greenhouse gas emissions✓**	M
		– CO2 emissions	S
		– CH4 emissions	S/M
		– N2O emissions	S/M
		– CFC emissions	S/M
	Conditions	♦ **Atmospheric concentrations of greenhouse gases; Global mean temperature**	S
	Responses	**Energy efficiency**	M/L
		– Energy intensity✓ (total primary energy supply per unit of GDP or per capita)	S
		– Economic and fiscal instruments (e.g prices and taxes, expenditures)	S/M
Ozone layer depletion	Pressures	♦ **Index of apparent consumption of ozone depleting substances (ODP)** ✓	M
		– Apparent consumption of CFCs/ and halons	
	Conditions	**Atmospheric concentrations of ODP**	S/M
		Ground level UV-B radiation	
		– Stratospheric ozone levels	S/M
	Responses	**CFC recovery rate**	M
Eutrophication	Pressures	Emissions of N and P in water and soil ➔ **Nutrient balance**	L
		– N and P from fertilizer use✓ and from livestock	S
	Conditions	**BOD/DO in inland waters, in marine waters✓**	S/M
		Concentration of N & P in inland waters , in marine waters	
	Responses	**Population connected to biological and/or chemical sewage treatment plants**	M/L
		– Population connected to sewage treatment plants	S
		– User charges for waste water treatment	M
		– Market share of phosphate-free detergents	S/M
Acidification	Pressures	**Index of acidifying substances**	M/L
		– Emissions of NOx and SOx	S
	Conditions	**Exceedance of critical loads of pH in water & soil**	M/L
		– Concentrations in acid precipitation	S
	Responses	**% of car fleet equipped with catalytic converters**	S/M
		Capacity of SOx and NOx abatement equipment of stationary sources	M/L
Toxic contamination	Pressures	**Emissions of heavy metals**	M/L
		Emissions of organic compounds	L
		– Consumption of pesticides✓	S/M
	Conditions	**Concentration of heavy metals & organic compounds in env. media & in living species**	L
		– Concentration of heavy metals in rivers	S/M
	Responses	**Changes of toxic contents in products and production processes**	L
		– Market share of unleaded petrol	S
Urban environmental quality	Pressures	**Urban air emissions (SOx, NOx, VOC)**	M/L
		– Urban traffic density	M/S
		– Urban car ownership	S
		– Degree of urbanisation (urban population growth rates, urban land) ✓	S/M
	Conditions	**Population exposure to air pollution, to noise**	L/M
		– Concentrations of air pollutants✓	S
		Ambient water conditions in urban areas	M/L
	Responses	**Green space** (Areas protected from urban development)	M/L
		Economic, fiscal and regulatory instruments	M
		– Water treatment and noise abatement expenditure	S/M

Issue		Core indicators[7]	([8])
Biodiversity	Pressures	**Habitat alteration and land conversion from natural state** to be further developed (e.g.. road network density, change in land cover, etc.)	L
	Conditions	**Threatened or extinct species as a share of total species known✓**	S
		Area of key ecosystems✓	M
	Responses	**Protected areas as % of national territory✓ and by type of ecosystem**	S/L
		– Protected species	S
Cultural landscapes		Indicators to be further developed e.g. Presence of artificial elements, Sites protected for historical, cultural or aesthetic reasons	
Waste	Pressures	**Generation of waste (municipal, industrial, hazardous, nuclear) ✓**	S
		– Movements of hazardous waste	S
	Responses	**Waste minimisation** (to be further developed)	L
		– Recycling rates✓	S/M
		– Economic and fiscal instruments, expenditures	M
Water resources	Pressures	**Intensity of use of water resources ✓** (abstractions/available resources)	S
	Conditions	**Frequency, duration and extent of water shortages**	M/L
	Responses	**Water prices and user charges for sewage treatment**	S/M
Forest resources	Pressures	**Intensity of forest resource use ✓** (actual harvest/productive capacity)	M
	Conditions	**Area✓, volume and structure of forests**	S/M
	Responses	**Forest area management and protection** (e.g. % of protected forest area in total forest area; % of harvest area successfully regenerated of afforested)	M/L
Fish resources	Pressures	**Fish catches✓**	S
	Conditions	**Size of spawning stocks**	M
	Responses	**Fishing quotas**	S/M
Soil degradation (desertification & erosion)	Pressures	**Erosion risks: potential and actual use of land for agriculture**	L
		– Change in land use	S
	Conditions	**Degree of top soil losses**	M/L
	Responses	**Rehabilitated areas**	M/L
Material resources (new issue)		**Intensity of use of material resources✓** (Indicators to be developed, link to Material Flow Accounting)	
Socio-economic, sectoral and general indicators *(not attributable to specific environmental issues)*	Pressures	**Population growth & density✓**	S
		Growth and structure of GDP✓	S
		Private & government final consumption expenditure	S
		Industrial production	S
		Structure of energy supply✓	S
		Road traffic volumes;	S
		Stock of road vehicles	S
		Agricultural production	S
	Responses	**Environmental expenditure**	M/L
		– Pollution abatement and control expenditure	S/M
		– Official Development Assistance✓ (indicator added on the basis of experience with environmental performance reviews)	S
		Public opinion	S

2.1.3.4 OECD KEI

« KEY endorsed by OECD Environment Ministers, are a reduced set of core indicators, selected from the OECD Core Set, that serve wider communication purposes. They inform the general public and provide key signals to policymakers..” (OECD 2005)

POLLUTION ISSUES		**Available indicators***	**Medium term indicators****
Climate change	1.	CO2 emission intensities	Index of greenhouse gas emissions
Ozone layer	2.	Indices of apparent consumption of ozone depleting substances (ODS)	Same, plus aggregation into one index of apparent consumption of ODS
Air quality	3.	SOx and NOx emission intensities	Population exposure to air pollution
Waste generation	4.	Municipal waste generation intensities	Total waste generation intensities, Indicators derived from material flow accounting
Freshwater quality	5.	Waste water treatment connection rates	Pollution loads to water bodies
NATURAL RESOURCES & ASSETS			
Freshwater resources	6.	Intensity of use of water resources	Same plus sub-national breakdown
Forest resources	7.	Intensity of use of forest resources	Same
Fish resources	8.	Intensity of use of fish resources	Same plus closer link to available resources
Energy resources	9.	Intensity of energy use	Energy efficiency index
Biodiversity	10.	Threatened species	Species and habitat or ecosystem diversity Area of key ecosystems

** indicators for which data are available for a majority of OECD countries and that are presented in this report*

*** indicators that require further specification and development (availability of basic data sets, underlying concepts and definitions).*

2.1.3.5 OECD SEI (Transport)

"SEI are designed to help integrate environmental concerns into sectoral policies. Each set focuses on a specific sector (transport, energy, household consumption, tourism, agriculture). Indicators are classified following an adjusted PSR model reflecting: sectoral trends of environmental significance; their interactions with the environment (including positive and negative effects); and related economic and policy considerations." (OECD 2005)

Table 1. **OECD set of transport-environment indicators**

	*Policy relevance	*Analytical soundness	*Measurability	
			Data availability	Data quality
SECTORAL TRENDS AND PATTERNS OF ENVIRONMENTAL SIGNIFICANCE				
A. Overall traffic trends and modal split				
♦ Passenger transport trends by mode	1	1	2	2/3
♦ Freight transport trends by mode	1	1	2	2/3
♦ Road traffic trends and densities	1	1	1/ 2	2
♦ Trends of airport traffic	2	1	1/ 2	1
B. Infrastructure				
♦ Capital expenditure by mode	1	2	1	2
♦ Road network length and density	1	1	1	1
♦ Rail network length and density	1	1	1	1
C. Vehicles and mobile equipment				
♦ Road vehicle stocks	1	1	1	1
♦ Structure of road vehicle fleet	1	1	2	2
♦ Private car ownership	1	1	1	1
D. Energy use				
♦ Final energy consumption by the transport sector	1	1	1	1
♦ Consumption of road fuels	1	1	1	1
INTERACTIONS WITH THE ENVIRONMENT				
E. Land use				
♦ Change in land use by transport infrastructure	1	1	2	2/3
♦ Access to basic services	1	2	3	3
F. Air pollution				
♦ Transport emissions and emission intensities	1	1	2	2
♦ Population exposed to air pollution from transport	1	1	2	2/3
G. Water pollution				
♦ Oil released from marine transport	1	1	2	2
H. Noise				
♦ Population exposed to transport noise ≥ 65db(A)	1	1	2	2/3
I. Waste				
♦ Transport-related waste and related recovery rates	1	1	2	-
♦ Hazardous waste imported or exported	1	1	2	2
J. Risk and safety				
♦ Road traffic fatalities	1	1	1	2
♦ Hazardous material transported by mode	1	1	2	-
ECONOMIC AND POLICY ASPECTS				
K. Environmental damage				
♦ Environmental damage relating to transport	1	1	3	3
♦ Social cost of transport	1	1	3	3
L. Environmental expenditure				
♦ Total expenditure on pollution prevention and clean-up	1	2	2	-
♦ R&D expenditure on "eco-vehicles"	1	2	3	-
♦ R&D expenditure on clean transport fuels	1	2	3	-
M. Taxation and subsidies				
♦ Direct subsidies to transport	1	2	3	-
♦ Total economic subsidies to transport	1	2	3	-
♦ Relative taxation of vehicles and vehicle use	1	2	2	-
N. Price structures				
♦ Structure of road fuel prices	1	1	1	1
♦ Trends in public transport prices	1	2	3	3
O. Trade and environment				
♦ Indicators to be developed (e.g. trends in international transport of goods, relative importance of cross-border vs. domestic transport)	2	2	2	-

* Classifications used for evaluating the indicators: policy relevance (1=high; 2=medium; 3=low) ; analytical soundness (1=good; 2=average; 3=poor); measurability in terms of data availability (1=short term; 2=medium term; 3=long term) and of data quality including international comparability (1=good; 2=average; 3=poor).

2.1.3.6 OECD Indicators derived from Environmental Accounting and DEI

"Indicators derived from Environmental Accounting are designed to help integrate environmental concerns into economic and resource management policies. Focus is on: environmental expenditure accounts; physical natural resource accounts, related to sustainable management of natural resources; and physical material flow accounts, related to the efficiency and productivity of material resource use.

DEI measure the decoupling of environmental pressure from economic growth. In conjunction with other indicators used in OECD country reviews, they are valuable tools for determining whether countries are on track towards sustainable development. Most DEIs are derived from other indicator sets and further broken down to reflect underlying drivers and structural changes." (OECD 2005)

No list available at this time for this two kind of indicators related to SD.

2.1.4 WB Sustainability Matrix 1995

Issue	Agenda 21 chapter	Driving force indicator	State indicator	Response indicator
Environmental				
Sources		*Resource depletion index (X)	.....	.....
Water (excluding oceans)	18	Withdrawal/availability	Water use/population	*Water charges/costs of provision*
		.....	Biological oxygen demand and chemical oxygen demand in water	.....
Fisheries	-	**Catches of marine species*	.....	.....
Forests	11	*Roundwood production*	*Forest area/total area*	Reforestation rate
		Deforestation rate	Standing timber (^)	*Stumpage fees/price of timber* (^)
		.....	*Quality of forest cover (?)	.....
Land: land management	10	*Land use changes	**Human-induced soil degradation*	*Land management techniques (^)
		.....	*Soil erosion risk index (^)	.....
Land: agriculture and rural development	14	Arable land per capita	*Cropland/natural capital* (^)	Rural to urban terms of trade
		*Use of fertilizers and pesticides (^)	Area with salinization or waterlogging	Expenditures on extension services (?)
Land: deserts and droughts	12	Fuelwood consumed per capita	*Desertification index (?)	.....
Subsoil assets	-	*Material inputs/GNP* (^)	*Subsoil assets/wealth* (^)	**Prices of inputs to outputs* (^)

		*Extraction rates	Years of proven reserves	Energy taxes and subsidies
		Energy consumption per capita	.....	Renewable/nonrenewable resources (?)
Sinks		*Pollution index (X)		
Solid waste	21	Industrial and municipal waste (X)	Waste disposal/waste generation (X)	Expenditures on waste collection (^)
Toxics	19, 20, 22	*Generation of toxics (^)	*Area of contaminated land (?)	..... (?)
Greenhouse gases	9	**Carbon dioxide and methane emmisions*	*Carbon dioxide and methane in atmosphere	Expenditires on abatement (^)
Stratospheric ozone	9	Production of CFCs	CFCs in atmosphere	Programs to phase out ozone-depleting substances
Life support		*Ecosystem risk index (X)		
Biodiversity	15	**Rate of habitat loss* (X)	**Natural capital/wealth* (^)	Protected area/total land area
		*Rate of species extinction (?)	*Number of threatened species	Protected areas/sensitive areas (^)
Oceans and coastal zones	17			
Human health impact		*Index of environmental impact (^)		
Water quality and access	6	Household water use per capita	Access to safe water	Percentage of population with sanitary services
		.....	Fecal coliform	.....
		.....	*Lead in water (?)	.....
Air quality	6	**Pollution load* (^)	**Ambient concentrations* (^)	.....
Other	6		*Environmental-related diseases (?)	.....
Social				
Demographics	5	Rate of population growth	Population density	Fertility rate
Health	6	*Burden of disease (DALYs)* (^)	Life expectancy	Health expenditures/GNP
		Calorie intake per capita	Infant mortality rate	.....
Education	16	School enrollment	Adult literacy rate	Education expenditures per capita

			Educational attainment (^)	.....
Human settlements		Rate of urban population growth	Percentage of total population in urban areas	..... (?)
Housing	7	.....	*Shelter index (?)	Housinge expenditures/GNP
		.....	Marginal settlements (?)	.....
Infrastructure	7	Motor vehicles per capita	.....	Infrastructure expenditures/GNP
Economic				
Poverty	2, 3, 4	*GNP/population growth rate*	*Headcount and poverty gap indices*	Labor-intensive growth (?)
		Distribution of wealth	*Genuine saving/GNP* (^)	
		*Production-consumption patterns (?)	Net primary school enrollment rate by poverty status and gender	Targeted interventions
		Total fertility rate	Infant mortality rate, Percentage of population using family planning	Ependitures for basic social services/total public expenditures
Financial resources	33	Per capita wealth	Environmental protection expenditures per capita	Investment/GNP
		.....	.....	*Environmental taxes + subsidies/GNP* (?)
		.....	.....	New environmentally sustainable development funding (?)
Transfer of technology	34			
Productivity	-	NNP'/wealth (^)	*NNP'/GNP* (^)	*Intermediate inputs/GNP* (^)
		Unemployment rate	Manufacturing/GNP	Capital/output ratio (^)
Institutional	8, 38-40	..... (?)	*Mandated environmental assessments (?)	*Ratifications of international conventions (?)

2.1.5 World Resource Institute of SDI (1996)

World Resources Institute, World Resources: A Guide to the Global Environment 1996 - 1997. Oxford University Press, New York. 1996

Basic Economic Indicators	• Gross National and Domestic Product • Official development assistance and external debt • World community indexes and prices
Population and Human Development	• Size and growth of population and labor force • Trends in births, life expectancy, fertility and age structure
Forests and Land Cover	• Land area and use • Forest resources • Wood production and trade
Food and Agriculture	• Food and agriculture production • Agricultural Inputs • Livestock populations and grain consumed as feed • Food trade and aid
Biodiversity	• National and international protection of natural areas • Globally threatened species: mammals, birds, and higher plants • Globally threatened species: reptiles, amphibians, and fish
Energy and Materials	• Commercial energy production • Energy consumption • Reserves and resources of commercial energy • Production, consumption and reserves of selected metals • Industrial waste in selected countries
Water and Fisheries	• Freshwater resources and withdrawals • Wastewater treatment • Marine fisheries, yield, and state of exploitation • Marine and freshwater catches, aquaculture and fish consumption
Atmosphere and Climate	• CO_2 emissions from industrial processes • Other greenhouse gas emissions • Atmospheric concentrations of greenhouse and ozone-depleting gases • World CO_2 emissions from Fossil fuel consumption and cement manufacture • Common anthropogenic pollutants

	• Inventories of national Greenhouse gas emissions

2.1.6 Balaton Group Indicators and Information Systems for SD (1996)

Natural Capital	Built Capital	Human and Social Capital	Ultimate Ends (Beloved Indicators)
• Renewable resources used/Natural resources used; • Time to oil or gas depletion/Lead time for renewable substitute; • Ecological footprint; • Agricultural land loss (because of urbanization, desertification, erosion)/total agricultural land; • Loss of primary forests/total primary forests remaining; • Total identified reserves of nonrenewables/annual depletion; • Unit of effort necessary to add a unit of identified reserves of nonrenewables; • Fish caught per unit of fishing effort; • Soil organic matter content; • Energy consumption per capita; • Output to sink/capacity of sink to absorb or assimilate (esp.for CO2) • CO2 emission per capita, relative to "fair earthshare;" • CO2 emissions/economic output; • Quality of river water entering a country/quality leaving a country • Rate of change in a number of persistent chemicals in the environment; • Number of synthetic chemicals in use; • Area used for environmentally compatible agriculture/area used for chemical intensive agriculture; • Percent of streams you can drink from safely; • Rate of change of forest and wilderness area; • Number of endangered species; • Health cost of environmental pollution (in money or time spent in ill health).	• Average productive lifetime of capital; • Maintenance inputs to capital stocks/productive output of capital stock (consistent units, preferably physical. Inputs must include indirect as well as direct); • Capital stock/end use output; • Resource (material and energy) throughput/end use output; • Vehicle-kilometers per capita; • Vehicle-tons/GDP; • Food stocks/food consumption • Food miles (average distance an item of food travels before being eater); • Ratios (balance) between various forms of built capital.	• Life expectancy; • Child mortality rates; • Mortality rates for under 5-year olds; • Total fertility rate; • Net population growth; • Bottom percentile of educational level of 20 year olds; • Work distribution index (instead of unemployment rate); • Average layers of management between employees and owners; • Proportion of (undernourished + over-nourished) children; • Walking distance per capita per day; • Cycling distance per capita per day and other human power distances; • Problem stock/rate of problem solving (could be defined as government response time); • Income of the top 10%/Income of the bottom 10%; • (Lies told by politicians * number of people who hear those lies)/day; • Percent of GDP going to graft and corruption; • Number of people involved in making indicators; • Percent of lifetime necessary to secure survival needs; • Crime rate, especially juvenile crime rate; • Social conflicts index; • Average distance between creators and consumers of art and media; • Percent of elections where you get to vote for a politician you really like;	• Population of the local "totem" species (salmon in Seattle, eagles in Maine, seals in the Netherlands -- whatever local creature people love); • Time spent with other age groups (0-15, 15 - 30, 30 - 65, 65 and on); • Leisure time fraction or proportion of free time per person; • Time spent with relatives per year - or average distance between living places of members of extended family; • Hours per day spend outdoors (corrected by climate?); • Average number of minutes spent daily in meditation of any kind; • Percent of lifetime in meaningful, fulfilling activities; • Human openness in the streets and the squares (climate dependent); • Number and size of places of rest and beauty (e.g. forests, parks, temples, churches); • "Localness" of resource system: is the supply reflecting local resources and skills (related to diversity); • Flexibility in choosing transport mode and housing; • Average age of the trees in the forest; • Percent of scientists who feel they perfectly understand the natural system they study; • Difference between climate change damage estimates of economists and natural scientists; • Population of migrating songbirds; • Time spent in activities that I like to do/time spent in activities that I don't like to do; • Contentedness of those around me in the community; • Number of sustainability indicators in use.

2.2 Agricultural related SDI

Resituer le role des pratiques : Parler de la soutenabilité des systèmes agricoles, c'est évaluer les pratiques. Elle se dintingue des options de politiques, et elles constituent les contexts sectorielles de mise en œuvre.

2.2.1 lists of Agri-environmental and/or rural indicators

2.2.1.1 OECD LIST (2001)

I. AGRICULTURE IN THE BROADER ECONOMIC, SOCIAL AND ENVIRONMENTAL CONTEXT		
1 Contextual Information and Indicators		**2 Farm Financial Resources**
• *Agricultural GDP* • *Agricultural output* • *Farm employment* • *Farmer age/gender distribution* • *Farmer education* • *Number of farms* • *Agricultural support*	• ***Land use*** ☐ Stock of agricultural land ☐ Change in agricultural land ☐ Agricultural land use	• ***Farm income*** • ***Agri-environmental expenditure*** ☐ Public and private agri-environmental expenditure ☐ Expenditure on agri-environmental research
II. FARM MANAGEMENT AND THE ENVIRONMENT		
Farm Management		
• ***Whole farm management*** ☐ Environmental whole farm management plans ☐ Organic farming	• ***Nutrient management*** ☐ Nutrient management plans ☐ Soil tests • *Pest management* ☐ Use of non-chemical pest control methods ☐ Use of integrated pest management	• ***Soil and land management*** ☐ Soil cover ☐ Land management practices • *Irrigation and water management* ☐ Irrigation technology
III. USE OF FARM INPUTS AND NATURAL RESOURCES		
1 Nutrient Use	**2 Pesticide Use and Risks**	**3 Water Use**
• ***Nitrogen balance*** • ***Nitrogen efficiency***	• ***Pesticide use*** • ***Pesticide risk***	• ***Water use intensity*** • ***Water use efficiency*** ☐ technical efficiency ☐ economic efficiency • *Water stress*
IV. ENVIRONMENTAL IMPACTS OF AGRICULTURE		
1 Soil Quality	**3 Land Conservation**	**4 Greenhouse Gases**
• *Risk of soil erosion by*	• *Water retaining*	• *Gross agricultural greenhouse*

water • *Risk of soil erosion by wind*	*capacity*	*gas emissions*
2 Water Quality	• *Off-farm sediment flow (soil retaining capacity)*	
• *Water quality risk indicator* • *Water quality state indicator*		
5 Biodiversity	**6 Wildlife Habitats**	**7 Landscape**
• *Genetic diversity*	• *Intensively-farmed agricultural habitats*	• *Structure of landscapes* ☐ Environmental features and land use patterns ☐ Man-made objects (cultural features)
• *Species diversity* ☐ Wild species ☐ Non-native species	• *Semi-natural agricultural habitats*	
	• *Uncultivated natural*	
	• *Habitat matrix*	
• *Eco-system diversity* (see Wildlife Habitats)		• *Landscape management*
		• *Landscape costs and benefits*

2.2.1.2 Italian LIST

		Social dimension	**DPSIR**
1	**Human capital**	Share of agriculture employment	S
2		Age of farmers	S
3		Differences among female and male employment shares	S
4		Farmer educational level	S
5	**Equity**	Annual variation of rural population (Town level)	D
		Economic dimension	
6	**Production efficiency**	Agriculture value added per labour unit	D
7		Agriculture value added per hectare	D
8	**Economic vitality**	On-farm and off-farm labour of farmers	D
9	**Competitiveness**	Agri-food exports / GNP	D
10		Gross fixed investments / GNP	S
		Environmental dimension	
11	**Soil**	Agricultural area / Overall regional area	D
12		Livestock units per hectare	P
13		Specie composition of breading	P
14		Nutrient balance	P
15		Pesticides consumption per hectare	P
16		Fertiliser consumption per hectare	P
17		Nutrient leaching	P
18	**Air**	Methane emissions	S
19		Nitrogen emissions	S
20		Energy direct consumption	D
21	**Water**	Irrigated area / agricultural area	D
22		Irrigation systems	P
23		Supply source	D
24	**Biodiversity**	Protected areas	R
25		Forestry area / total area	P
26		Fired walls area	P
27		New forestry area (variation respect to 1995)	P
28		Organic farming area	R
29		Area benefiting from agri-environment support	R
30		Regional budget for environmental protection	R
31		Specie condition	S
32	**Landscape**	Marginalisation	D
33		Intensification / extensification	D
34		Specialisation	D
35		Concetration	D

2.2.2 SRL-FSELM (Rigby and al. 2000)

Table 1 Matrix for sustainability indicators

Dimensions (FESLM)	Assets (SRL)				
	Natural	*Physical*	*Financial*	*Human*	*Social*
Productivity	Levels and trends for: Productivity (per unit of land, per unit of water [irrigated systems])		Levels and trends for: Rates of return on investment [financial outlay]	Total earned income (on-farm and off-farm) per working household member	Active cooperative associations, organisations; Government extension services; Labour or asset sharing.
Economic viability		Return on fixed capital assets. Access to markets	Farm gross margins Farm profit Net household income	Affordability of health, education	Contributions to / claims on social welfare.
Production risk / security	Pest/ disease risks. Months with lack of water Flood and fire risk Cultivation of 'marginal' land	(Investment in) flood control and irrigation infrastructure.	Output and input price variability; Savings and debt levels Credit access Income diversity Insurance Welfare/pensions	Health status Educational attainment Unemployment	Security of crop, livestock from theft, damage; Security of land use rights Government food security measures; Gifts, loans in times of need
Protection from degradation	Soil 'quality', Soil erosion Pesticide use and toxicity levels Agro-biodiversity Ground cover (deforestation) Conservation technologies				Environmental; organisations, campaigns; Local natural resource management authorities, organisations
Social acceptability	Conflicts over access to, or tenure of, land, water etc	Distribution of access to infrastructure, equipment	Income distribution within society / 'community' / household	Inequality in access to health / education / training	Accountability of elected or customary representation or leadership Social exclusion.

Table 2 Sustainability Indicators: summary of measurement or data requirements

National level	*Economic statistics* on: • Output and input prices and price trends • Interest rates, inflation rates • Taxation rates (rural compared to urban, if different) • Social welfare benefits (if any)
'District' level S Africa: magisterial district Uganda: sub-county Secondary sources and key informant interviews	District (discriminate to sub-county in Uganda, if possible) *secondary data*: • Census: population, population growth rate • % population with access to electricity, piped water • Health statistics: child mortality, malnutrition rates, life expectancy (discriminated by sex), medical charges • Educational statistics: % enrolment and drop-out rates of school age girls and boys (primary and secondary) • School fees. • Agricultural production trends (total areas and yields per hectare), Output and input prices and price trends, *Estimates* (from reports, interviews) of: • Incidence of water shortage / drought (months) in recent years (excluding normal rainfall seasonality) • % loss of output due to pests and diseases in recent years • Incidence of flood damage in recent years • Incidence of fire damage in recent years • % agricultural land provided with irrigation • % agricultural land provided with flood protection *Estimates* (from comparison of old and recent Aerial photos / satellite image, or from research studies) of: Vegetation change: tree cover decline, or bush encroachment (on pasture)
Village or 'community' level Semi-structured interviews with stakeholder groups to provide information about the importance of, and semi-quantitative estimates of extent of:	• Population, population change • % of population with access to electricity, piped water. • Time or cost to reach markets • Rates of tax, or subsidy as % of costs, revenues. • Credit access, interest rates • Local or customary control over land • Conflicts over land, water • Production foregone or increased costs as a result of security problems (insecurity of land tenure, crop or livestock theft) • Months of water shortage in last five years • Incidence of fire, flood damage in the past five years • Labour or asset sharing by households • Gifts, loans from kin, friends, religious groups in times of need • Frequency of government emergency relief • Benefits from government technical services • Benefits from commercial technical services • Benefits from voluntary associations • Environmental associations: membership, campaigns. • Any regulatory authority influencing land use/conservation

Household or farm level A questionnaire survey conducted on a sample of farm households to include the primary stakeholder groups identified in the stakeholder analysis:	• Farm output and input prices and trends • Number of working and dependent household members (resident or contributing financially) • Amount of marketed production • Value of marketed production • Value of non-marketed production ? • Total earned income of working household members • Cash value of pensions • Household expenditure • % of household income earned and managed by women • Household savings, debt • Credit access, interest rates • Health, educational, and employment status of household members • Rates of tax or subsidy as % of costs or revenues • Production foregone or increased costs due to security problems (insecurity of land tenure, crop or livestock theft) • Gifts. Loans from kin, friends, religious groups in times of need • Benefits from voluntary associations, government services • Crop insurance • % loss over past three years due to pests, diseases • months of water shortage during past three years • Incidence of flood or fire damage in last three years • % land with irrigation • % land protected from flood • Pesticide applications: products, dosage and frequency • Agro-biodiversity: % of farm occupied by different crops, fallow • Conservation measures used (mulch, organic manure, tillage, terracing)
Plot level A survey of a sample of fields for each stakeholder group (does not have to be undertaken at the same time as farm interview). The survey will include an interview to ascertain cultivation history and productivity, and sampling for analysis.	• Number of years of cultivation (fallow, rotation history) • Fertiliser rates • Conservation measures used (organic manure, tillage, terracing) • Yield of crop or livestock per hectare • Soil sample analysis for Soil quality measurement (available (Bray 1) P ? organic carbon?) • Soil erosion assessment (erosion bridge measurements if possible) • Range quality assessment

2.2.3 IRENA

Domain	Sub-domain	Explanation	No.	Indicator
		expansion/withdrawal, intensification/extensification, specialisation/diversification, marginalisation.	17	Marginalisation
Pressures and Benefits	*Pollution*	Build up of nutrients and pesticide residues in soil and water, ammonia and methane emissions	18	Gross nutrient balance
			18sub	Atmospheric emissions of ammonia
			19	Emissions of methane and nitrous oxide
			20	Pesticide soil contamination
			21	Use of sewage sludge
	Resource depletion	Inappropriate use of water and soil, destruction of natural and semi-natural habitats, loss of genetic diversity.	22	Water abstraction
			23	Soil erosion
			24	Land cover change
			25	Genetic diversity
	Preservation and enhancement of the environment	Creation/preservation of landscapes, habitats, land cover, preservation of genetic diversity in agriculture, production of renewable energy sources	26	High nature value (farmland) areas
			27	Production of renewable energy (by source)
Site specific State	*Biodiversity*	Diversity of species	28	Population trends of farmland birds
	Natural resources	Soil quality, water quantity and quality	29	Soil quality
			30	Nitrates/pesticides in water
			31	Ground water levels
	Landscape	State of the landscape, i.e. cultivated, partly semi-natural, space within which agricultural production takes place and which is characterised by the totality of its biophysical, geophysical and cultural features	32	Landscape state
Global Impact	*Habitats and biodiversity*	Global environmental impact of agriculture at the national or EU level. A link needs to be established between the global impact and the environmental effects of agricultural activities at local level.	33	Impact on habitats and biodiversity
	Natural resources		34.1	Agricultural share of GHG emissions
			34.2	Agricultural share of nitrate contamination
			34.3	Agricultural share of water use
	Landscape diversity		35	Impact on landscape diversity
Responses	*Public policy*	Farming activities are heavily influenced by agricultural and environmental policies and sensitive to input and product price signals. Moreover, changes in technology, farmers' skills, and consumers and producers attitudes affect production methods and agricultural practices.	1	Area under agri-environment support
			2	Regional levels of good farming practice
			3	Regional levels of environmental targets
			4	Area under nature protection
	Market signals		5.1	Organic producer prices and market share
			5.2	Organic farm incomes
	Technology and skills		6	Holders' training levels
	Attitudes		7	Area under organic farming

Domain	Sub-domain	Explanation	No.	Indicator
Driving forces	*Input use*	Agriculture is the product of local farm structures and farming systems, characterised by: Specific use of inputs (chemicals, energy and water),	8	Mineral fertiliser consumption
			9	Consumption of pesticides
			10	Water use (intensity)
			11	Energy use
	Land use	Land use/cover (allocation of farmland to different uses, including cropping and stocking patterns, and adoption of irrigations.	12	Land use change
			13	Cropping/livestock patterns
		Farm management practices (soil cover, tillage practices and handling of farm manure and wastes).	14	Farm management practices
	Trends	Key trends in farming activities at an aggregate level, i.e.	15	Intensification/extensification
			16	Specialisation/diversification

2.2.4 ELISA

Driving force indicators

LU.1 Share of irrigated area
LU.2 Yield of cereals
LU.3 Share of farms with > 50% cereals
LU.4 Share of UAA in total area

LU.5 Livestock density
N.1 N-discharge

N.2 Nitrate surplus
P.1a Direct usage data per pesticide
P.1b Sales data per pesticide
P.1c Pesticides cost per crop
P.1d Estimated usage data per crop

P.2a+b Pesticide risk

State indicators

S.1 Water erosion
S.2 Wind erosion
S.3 Soil compaction
S.4 Pesticides in soil
W.1 Nitrate in rivers
W.2 Nitrate in groundwater
W.3 Nitrate in drinking water
W.4 Pesticides in groundwater
W.5 Pesticides in rivers/surface waters
W.6 Groundwater level
B.1 Spatial complexity
B.2 Corridors and linkages between habitat types
B.3 Size/% of characteristic habitat types
B.4 Flagship species
B.5 Species richness
B.6 Species population trends
B.7 Genetic diversity in semi-natural agro-ecosystems
B.8 Genetic diversity in farm species
L.1 Biophysical adequateness of land use

L.2 Openness versus closedness
L.3 Adequateness of key cultural features
L.4 Land recognized for its scenic or scientific value

2.2.5 PAIS

Table 1: Proposal for Landscape indicators

Landscape domain	Indicator Theme	Indicator Name:	Indicator Number:
Formal landscape features	Landscape composition	Stock and change of Used Agricultural Area	1
		Stock and change of arable land	2
		Stock and change of grassland	3
		Stock and change of forest areas	4
		Stock and change of semi-natural and natural land	5
		Stock and change of built up areas	6
	Stock and change of different land cover/use classes	Conversion rate	7
		Modification rate	8
		Extensification rate	9
		Intensification rate	10
		Reclamation rate	11
		Afforestation rate	12
	Landscape configuration	Diversity indices: - Shannon Diversity Index - Heterogeneity Index (HIX) - Interspersion and Juxtaposition - TerUti based homogeneity/heterogeneity indicators	13
		Patch Shape of agricultural parcels	14
		Length and distribution of different edges	15
		Fragmentation Indices	16
	Natural landscape features	Stock and change of "broad, semi-natural and natural habitats/biotopes	17
		Stock and change of valuable biotopes and habitats in agricultural landscapes (area features) managed by farmers - Extensive managed grassland areas - Traditionally managed orchards - Old olive grooves	18
		Stock and Change of linear habitats and biotopes in agricultural landscapes (Saumbiotope) - Arable field margins - Woodland margins - Grass margins - River banks (streamside vegetated margins) - Hedges	19
		Stock and Change of point habitats and biotopes in agricultural landscapes	20

	Historical-cultural landscape features	Stock and change of historical – cultural landscape area features - Historical agricultural parcel pattern	21
		Stock and change of historical – cultural landscape linear features - Stone walls - Terraces - Ancient roads	22
		Stock and change of historical – cultural landscape point features	23
	Present anthropogenic landscape features	Stock and change of present- anthropogenic landscape area features - urban sprawl	24
		Stock and change of present- anthropogenic landscape linear features - traffic infrastructure	25
		Stock and change of present- anthropogenic landscape point features - Wind turbines	26
		Hemerobie (naturalness) - Index	27
Human perception, social value indicators and landscape valuation		Willingness to Pay for provision of agricultural landscapes or landscape features	28
Landscape Management conservation and protection		Change in the share of farmers (committed to agri-environmental schemes, explicitly aiming at landscape conservation) from total number of farmers	29
		Change in the percentage of financial expenditure of agri- environmental schemes (per hectare or per farmer involved)	30
		Share of area covered by agri-environmental schemes from total Used Agricultural Area (UAA)	31
		Area under specific farming or management practices aiming at landscape conservation (traditional agricultural land use practices) - orchards - olive grooves - alpine meadows - extensive grassland management schemes	32
		Length of "green" linear landscape features maintained and/or restored by farmers - hedges - grass margins in arable field - buffer zones along rivers and streams stone walls - terraces - transhumance tracks	33
		Number of farmers participating in training programmes concerned environmental friendly management practices, landscape conservation etc.	34
		Used Agricultural Area (UAA) within protected sites (according to IUCN categories)	35

Table 2: Proposal for indicators related to Agricultural Practices			
Indicator level	Issue	Indicator	No.
Contextual Indicator	Main agricultural land use type	Area of agricultural land	1
		Arable land	2
		Grassland	3
		Wetlands	4
		Shrubs	5
	Cultivated crops	Acreage of cultivated crops	6
		Yields of crops	7
		Crop diversity	8
Farm management	Farm management systems	Organic Farming	9
		Integrated Plant Cultivation (IPC)	10
		Farm management with environmental monitoring	11
		Farm management according to good agricultural practice	12
	Extensification	Extensification of farmland by discontinuation of farming	13
		Extensification by introduction of extensive cultivation methods	14
Field management	Soil protection	Soil cover by crops	15
		Soil cover by stubble and mulch	16
		Humus balance	17
	Cultivation methods	Direct drilling	18
		Tillage intensity	19
	Irrigation	Water consumption	20
		Irrigation technique	21
	Field margins	Field margin cultivation	22
		Hedgerow cultivation	23

Table 3: Some Key Rural Development Indicators			
Theme	**Issue**	**Indicator name**	**No.**
Population and Migration	Demography	Population density	1
		% population aged 16 or under	2
		% population aged 65 or over	3
		Infant mortality rate	4
	Population Change	Average annual population change	5
		Regional net migration balance	6
Social well-being	Service provision	ility to public services	7
	Employment	% resident workforce working outside area	8
		Rural employment rate	9
	Quality of employment	% low skilled and high skilled workers	10
		% of part-time workers	11
		% of employees on short-term contract and long-term contracts	12
		% workforce self-employed	
	Income	seholds in receipt of social payments	14
		Average earnings per capita	15
		Household disposable income	16
	Housing accessibility	No. of second homes	17
		Average house price deviation from national average	18
		Affordability gap	19
		Rate of transactions (house sales)	20
		% turnover in rented sector	21
Economic Structure & Performance (competitiveness)	Enterprise	Average no. of patents	22
		No. of patent applications	23
		R&D expenditure	24
		New business formation rate	25
		GVA per capita in manufacturing	26
		% GVA in high-technology sectors	27
	Human capital	No. of university students	28
		Share of workforce with higher qualification	29
	Business infrastructure	Supply of broadband services	30
Economic Structure & Performance (diversification of rural economies)	Sectoral shares	employment shares: high and low tech manufacturing	31
		employment shares: shift share analysis	32
		% foreign owned companies	33
		% employment in foreign owned companies by sector (manufacturing and tradable services)	34
		Enterprise size structure by employee numbers	35
		Net revenue by enterprise sector	36
	Farm households	% share of pluriactive farm households	37
		e from non-farming activities	38
		% income from off-farm activities	39
	Tourism & recreation	No. of bedspaces per 1,000 inhabitants	40
		No. employed in rural tourism accommodation providers	41
		Accommodation occupancy rate	42
		Share of rural enterprises in total tourism turnover	43

2.2.6 MAFF (UK 2000)

Issue	Area	Indicator
		1 Agricultural assets and liabilities
	Structure of the agriculture industry	2 Age of farmers
A. Agriculture within		3 Percentage of holdings that are tenanted
the rural economy		4 EU Producer Support Estimate (PSE)
and society	Farm financial resources	5 Payments to farmers for agri-environment purposes
		6 Total income from farming
		7 Average earnings of agricultural workers
	Agricultural productivity	8 Agricultural productivity
	Agricultural employment	9 Agricultural employment
	Management	10 Adoption of farm management systems
B. Farm management systems	Organic farming	11 Area converted to organic farming
	Codes of Practice	12 Knowledge of Codes of Good Agricultural Practice
		13 Pesticides in rivers
		14 Pesticides in groundwater
	Pesticide use	15 Quantity of pesticide active ingredients used
		16 Spray area treated with pesticides
		17 Pesticide residues in food
		18 Nitrate and phosphorus losses from agriculture
C. Input use	Nutrients	19 Phosphorus levels of agricultural topsoils
		20 Manure management
		21 Ammonia emissions from agriculture
	Greenhouse gas emissions	22 Emissions of methane and nitrous oxide from agriculture
	Energy	23 Direct energy consumption by farms
		24 Trends in indirect energy inputs to agriculture
	Water	25 Use of water for irrigation
		26 Organic matter content of agricultural topsoils
D. Resource use	Soil	27 Accumulation of heavy metals in agricultural topsoils
	Agricultural land	28 Area of agricultural land
		29 Change in land use from agriculture to hard development
	Non-food crops	30 Planting of non-food crops
	Environmental conservation	31 Area of agricultural land under commitment to environmental conservation
	Landscape	32 Characteristic features of farmland
E. Conservation value of agricultural land	Habitats	33 Area of cereal field margins under environmental management
		34 Area of semi-natural grassland
	Biodiversity	35 Populations of key farmland birds

2.2.7 Potential Biological, Chemical, and Physical Indicators of Soil Quality

From Karlen and al. 2001

Biological	*Chemical*	*Physical*
Point-scale indicators		
Microbial biomass	pH	Aggregate stability
Potential N mineralization	Organic C and N	Aggregate size distribution
Particulate organic matter	Extractable macronutrients	Bulk density
Respiration	Electrical conductivity	Porosity
Earthworms	Micronutrient concentrations	Penetration resistance
Microbial communities	Heavy metals	Water-filled pore space
Soil enzymes	CEC and cation ratios	Profile depth
Fatty acid profiles	Cesium-137 distribution	Crust formation and strength
Mycorrhiza populations	Xenobiotic loadings	Infiltration
Field-, farm,- or watershed-scale indicators		
Crop yield	Soil organic matter changes	Topsoil thickness and color
Weed infestations	Nutrient loading or mining	Compaction or ease of tillage
Disease pressure	Heavy metal accumulation	Ponding (infiltration)
Nutrient deficiencies	Changes in salinity	Rill and gully erosion
Growth characteristics	Leaching or runoff losses	Surface residue cover
Regional-, national-, or international-scale indicators		
Productivity (yield stability)	Acidification	Desertification
Species richness, diversity	Salinization	Loss of vegetative cover
Keystone species and ecosystem engineers	Water quality changes	Wind and water erosion
Biomass, density and abundance	Air quality changes (dust and chemical transport)	Siltation of rivers and lakes

An adapted form of the index from Karlen and al. (1994) was used to evaluate the soil quality

3 MFA, SFA and LCA

3.1 Physical economy approaches by Daniels and Moore (2002)

We indicate the direct use of sustainability criteria for each technique (+ means when sustainability criteria is included occasionally, ++ means when sustainability criteria is typically included, and +++ means when sustainability criteria is a defining feature of the approach).

Total Material Requirement and Output (+)

Total material requirement and output (TMRO) is a material flow accounting approach that quantifies the physical exchange of aggregated material flows between national economies and the environment. Initial studies based on the total material requirements (TMRs) of nations considered only environmental inputs and did not fully embrace materials balance concepts. More recent extensions, however, include (total) material outputs to the environment and the rest of the world's economy and are consistent with materials balance principles. Material flows are treated at aggregated levels and consist of domestic resource extraction and imports (inputs) and domestic releases to the environment and exports (outputs). The TMRO approach generally involves the measurement of material flows induced at any stage of the life cycle of economic output, including "hidden flows" or "ecological rucksacks" that stay outside the economy and have no formal economic value. Upstream or downstream flows associated with imports and exports (resource requirements or emissions) may be considered. Environment is compartmented in three major gateways where material outputs are rejected: air, water and land. It is possible to weight the TMR by GDP to create a kind of global eco-efficiency index. To obtain sustainability indices from TMRO analyses, it is generally necessary to integrate other information concerning critical input and output thresholds or natural fluxes. Daniels (2002)notes that TMRO can be an operational tool to monitor resource demands in relation to Factor 4 or 10 eco-efficiency improvement targets (Factor 10 Club 1995). (Methodological guidelines can be found in Eurostat (2001) and representative examples in: Adriaanse and al. (1997); Matthews Matthews and al. (2000).

Bulk Internal Flow MFA (IFF Material Flow Balance Model Variant) (+)

The bulk internal flow material flow analysis (MFA-BIF) models developed as material flow balance models that focused on both material inputs and output flows and stock accumulations, induced by the entire societal metabolism of a given region. An essential principle is that of "materials balance" in order to derive consistent and balanced measures of material inputs and outputs across the economy-environment system boundary. The approach has also incorporated the identification and quantification of physical flows of "bulk" material categories within at least a limited number of subsystem components of the economic region under study. BIF-MFA models open the "black box" of the economy to measure material flows between major sectors, without the loudness and data requirement of PIOT models (Daniels, 2002) (Representative example: Hüttler and al. (1997).

Physical Input-Output Tables (+)

Physical input-output tables (PIOT) allow national-level analysis that extends upon conventional input-output methodology and classifications to incorporate environmental resource and waste output “sectors” to provide measures of the physical flow of materials and goods within the economic system and between the economic system and the natural environment. This approach, related to SEEA, involves the exhaustive physical coverage of the movement (origins and uses) of most environmentally relevant materials induced by an economic region (sometimes disaggregated to the level of elements or simple chemical compounds). The PIOT method traces how natural resources enter, are processed, and subsequently as commodities, are moved around the economy, used, and finally returned to the natural environment in the form of residuals. It undertakes the *detailed* investigation of inter-sectoral physical flows of environmental resources inputs and commodity weights and residuals. Considering this inter-sectoral specification and provision of a matrix of the transaction structure, PIOT has the ability to evaluate the cumulative environmental burden (total direct and indirect effect material requirements and pressures) of private consumption and other final demand for the products of different industries. (Representative examples: Gravgard Pederson (1998); Stahmer and al. (1998))

Substance Flow Analysis (++)

Substance flow analysis (SFA) focuses on material flows of just *one, chemically defined* substance, or a limited group of such substances through the metabolism of a relatively extensive, predefined geographic region. Within this region, all significant economic sources acting as the driving forces behind induced substance flows (levels and trends in substance emissions and accumulations, and concentration in the human economy and various environmental media) are considered. (Representative example: Van der Voet and al. (1996))

Ecological Footprint Analysis (+++) EF being a composite indicator, it is discussed in detail page 40.

Environmental Space (+++) has already been presented page 35.

Material Intensity per Unit Service (+)

Material intensity per unit service (MIPS) involves the identification of a single mass-based measure of the total, life-cycle-wide (or cradle-to-grave) primary material and energy requirement of environmentally significant economic output in the form of specific products, or forms of infrastructure or service delivery. The final MIPS measure is expressed as the ratio of the mass of material and energy inputs to physical (and sometimes monetary) measures of services provided as benefits to people. The result is a material “intensity” involved in the provision a specified level of service of the system under study and represents a measure of the anthropogenic ecological or environmental impact intensity of selected forms of economic output. (Representative example: Lehmann and Schmidt-Bleek (1993))

Life-Cycle Assessment (+)

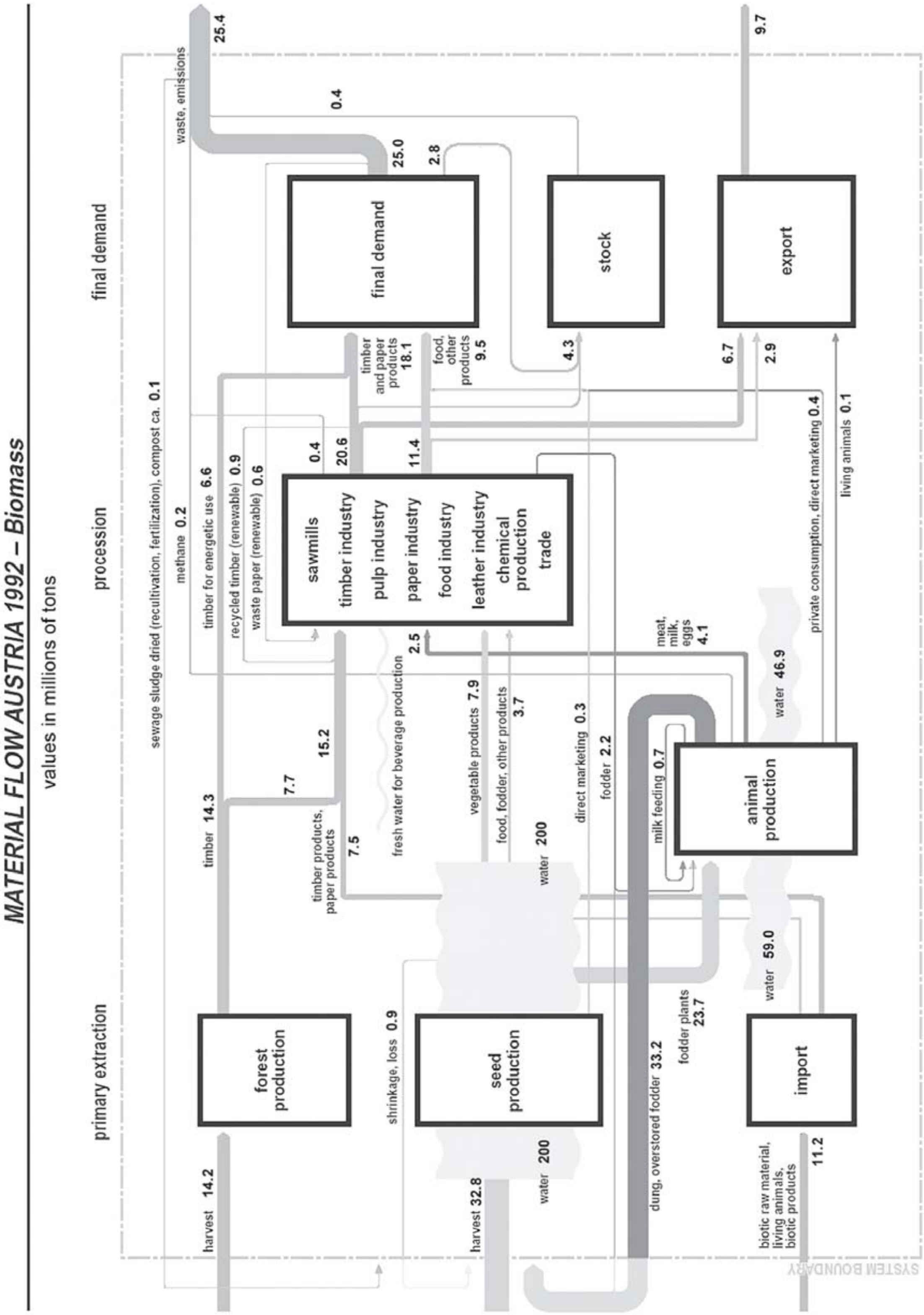
Life-cycle assessment (LCA) is an environmental management tool for identifying (and comparing) the whole life cycle, or cradle-to-grave, environmental impacts of the creation, marketing, transport and distribution, operation, and disposal of specific human artefacts. The approach is intrinsically holistic in nature and considers direct and, ideally, related processes and hidden, non-market flows of raw materials and intermediate inputs, and waste and other material and energy outputs associated with the entire existence or "product chain" or "system" (Guinee and al., 1993). The LCA procedure often involves a comparison of a small number of substitutable products assumed to provide a similar consumption service. (Representative example: Maclean and Lave (1998); Joönsson and al. (1998); (Saouter and van Hoof (2002)).

Sustainable Process Index (+++)

The sustainable process index (SPI) is based upon the calculation of the total land area required by any process, technology, or other economic activity in order (i) to sustainability provide natural material and energy resource flows and (ii) to maintain waste assimilation or "sink" services. It is a tool for assessing the ecological intensity and potential sustainability of one or a small number of processes or technological options for providing products or services. … The general aim of the indicator is to assess the consistency of a process or technology with respect to sustainable limits set by the natural environment, and the identification, selection, and promotion of "ecologically acceptable" process technologies. (Representative example: Krotscheck and Narodoslawsky (1996))

Box 3: brief description of the major approaches for quantifying the metabolism of physical economies from Daniels and Moore (2002) and Daniels (2002).

3.2 IFF MFA-BIF model for Austria



4 Criteria for indicator selection

Scientific quality	Relevance to Dimension	Data management	Methodological aspects	Communication / particpation	Policy relevance
Indicator really measures what it is supposed to detect	**To be completed in task 2.2.2-2.2.4 on thematic indicator**	Easy to measure and to document	*Distinguishes between causes and effects*	Transparent	With reference with target
indicator measures significant aspect	**Economic**	Availability and/or cost effective	*Uncorrelated, independent*	relevant to users	Timely and geographically linked with policy
Problem specific	Covers full cycle of the products	Comparability over time and space	Can be reproduced and repeated over time	user friendly	Addresses shared responsibility
unambiguous	...	Related to threshold	Reduces complexity	widely accepted	adapted to prospective analysis
Measurability	**Social**	Facilitates aggregation	Participation to SD unambiguous and quantifiable (existence of threshold)	*Reflects actual debates and trade-offs between SD dimensions*	Early warning
Stability and sensitivity	Integrates the sectoral specificity of reproduction (intergenerational aspects for agriculture for example)		Early warning	Informs about quality of life and well-being	Reflects actual debate and trade-off between SD dimension and identify priority of SD
	Clearly identify the community of reference (region, rural area, farmers)		adaptable to different object, scale and time (region, project, firm) or locally adapted	Allows self-evaluation and promote behavioural change	Allows self-evaluation (agricultural practices for example) and promote behavioural change

	Quality of life		*Address impact and benefits in each dimension*	*Parsimony*	Address main sectorial effects on SD
	...		Address quality of life		compare the rhythm of increase of threat and the rhythm of solution elaboration and implementation
	Environmental		*Equilibrate betweens SD dimensions and highlight links*		
	Covers full cycle of the ecosystem		Address the dependence between systems		
	Identify Critical loads of the ecosystem				
	Institutional				
	...				

Table 3: Criteria for the choice of indicators for global SDI. Assuming a framework already contains principles of SD (sustainability paradigm).

Normal style for criteria necessary for all indicator, in red for criteria for some indicator, *and in italic criteria for global coherence*.

5 Major works on agricultural system proprieties

For the proprieties of this agricultural system, we can rely on some of the major works in this area that have defined such properties specifically for agro-ecosystems:

- Conway (Conway, 1993a) has defined: productivity, stability, sustainability, and equity.
- FSELM (Smith and Dumanski, 1994) has defined: productivity, security, protection, viability and acceptability.
- ICSA (1996): maintenance of resource availability over time, adaptability and flexibility, vigour, resilience and stability, responsiveness to changes, self-reliance, empowerment.
- MESMIS has defined: productivity, stability, reliability resilience, adaptability, equity, self-reliance (self-empowerment).
- Other works are reviewed in Lopez-Ridaura and al. (2005).

MEMSIS, which is among the most recent initiatives, has the advantage of providing, in addition to proprieties adapted to agro-ecosystems, an interesting frame for identifying indicators most fit to representing each property. This identification involves putting in evidence, within a participative procedure, of "critical points" ' and criteria enabling diagnosis of the system's situation regarding them. This methodology could probably be used in SEAMLESS. The application of MEMSIS to Mexico by (Pérez-Grovas, 2000) and the organization of diagnostic criterion they propose is particularly interesting (see Table 4) to derive a usable frame for SEAMLESS permitting to integrate a good deal of indicators considered up to now for the PD2.2.2.

Indicators used for evaluating the sustainability of two coffee production systems in the Highlands of Chiapas, Mexico (*Union De Ejidos Majomut*) (Pérez-Grovas, 2000)

Attribute	Diagnostic criterion	Strategic indicators	Measurement method
Productivity	Efficiency	Yields	Sampling
		Produce quality	Random sampling to determine percent of aborted berries and defective berries
	Profitability	Marginal cost/benefit	Cost-benefit analysis
		Labour demand	Socio-economic survey
		Net income/total income	Socio-economic survey
Stability, resilience, reliability	Biological diversity	Number of managed species	Surveys of flora
	Economic diversity	Income from non-coffee crops	Census of non-coffee plants and products
		Market diversification	Coffee marketing process
	Biological vulnerability	Pest incidence	Random sampling in plots
		Erosion	Measuring in runoff plots
		Nutrient balance	Soil, compost and berry analyses
	Economic vulnerability	Input availability	Technical monitoring dossier per plot
		Fluctuations in coffee prices	History of coffee prices
	Social vulnerability	Permanence of coffee producers in the system	Majomut coffee producers' registry
Adaptability	Capacity for change	Producers and area cultivated per system	Majomut producers' registry
Equity	Distribution of benefits, and decision-making power	Decision-making mechanisms	Interviews with Majomut Directive Board
		Distribution of returns and benefits	Institutional survey
Self-reliance	Participation	Attendance to assemblies and other events	Institutional survey
	Training	Number of producers trained	Quantification of training courses
	Self-sufficiency	Reliance on external resources	Financial statistics of Majomut

Table 4 : Diagnostic criterion by attribute of agro-system (Pérez-Grovas, 2000)