Chapter 2
Indicators Assessment Systems

Marta Bottero

Abstract This chapter deals with the theme of environmental indicators in general, the principles and the fundamental definitions that regulate the use of the same. On the basis of experience gained with environmental indicators in the international field, we will consider the main models used for assessment in detail (first and foremost the DPSIR, Driving forces-Pressures-State-Impact-Responses), indicating the prerequisites and various fields of application. The paper studies various environmental indicator systems in depth, with the aggregation of the same in concise indexes to convey the information in an effective way for a specific target. The last part of the chapter contains a proposal for a table presenting the landscape indicators covered in the following chapters of the book.

Keywords Environmental indicators • DPSIR framework • Environmental assessment • Weighting and aggregation • Indicators presentation

2.1 The Use of Indicators: Environment and Landscape

2.1.1 Definition and Requirements of an Environmental Indicator

Landscape indicators have only recently been used in the field of analysis and for the assessment of territorial transformation. These indicators derive from more consolidated and structured models, referring to environmental indicators in general (DEFRA 2009; Eurostat 1999, 2009; International Institute for Sustainable Development 1999; UNCSD 2001, 2007; World Bank 2008).

M. Bottero (✉)
Dipartimento Casa-Città, Politecnico di Torino, viale Mattioli 39, 10125 Torino, Italy
e-mail: marta.bottero@polito.it

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The indicator is a parameter associated with an environmental phenomenon, which can provide information on the characteristics of the event in its global form (OECD 2003).

Its purpose is to indicate the state, or the variation in the state, of a phenomenon which cannot be measured directly. In fact the data, even if suitably presented, does not constitute an indicator, and can only be used as such when linked to a phenomenon other than that measured.

By using indicators we can obtain targeted information, in order to concisely represent the problems studied while maintaining the informative content of the analysis intact (Schmidt 1986).

Many experts agree that a good indicator must meet some fundamental requirements.

These requirements can be summed up as follows:

- *Representativeness:* the indicator must be clearly correlated with a certain phenomenon or certain characteristic we wish to measure or control; it must be highly correlated with the above-mentioned effect, with a minimum statistical dispersion; it must not be easily hidden by surrounding factors; it must be sufficiently valid in many similar situations, even if not identical;
- *Accessibility:* it must be easy to measure and if possible to monitor automatically; it must be easy to sample; it must have a analytic measuring threshold accessible with standard techniques;
- *Reliability:* it must have minimum systematic error values;
- *Effectiveness:* it must be directly and easily usable to quantify interventions, costs and benefits.

The informative content of an indicator depends greatly on:

- the *relevance*, in other words the importance of the characteristic measured for the knowledge of the phenomenon in question;
- the *specificity*, in other words the capacity to identify only the characteristics associated with the phenomenon in question;
- the *precision* of the measuring parameter, in other words the capacity to measure the state and variations of the characteristics at the in-depth level required.

In particular, several of the bodies that promoted the diffusion of environmental indicators have established criteria for specific selection and validation. The three main requirements established by the OECD (2003) are shown in Table 2.1.

In particular, the definition provided by the Landscape Observatory of Catalonia should be referred to for the analysis and assessment of landscape using environmental indicators. The landscape indicator is defined as a quantitative or qualitative element, which can be used to assess and monitor the evolution and state, public satisfaction, and the effectiveness of public and private initiatives for the improvement of the same.

Furthermore, Vallega (2008) emphasises that a landscape indicator is not merely an act of acknowledgment, but must also be an instrument of assessment. In other words it must assess the terms in which aspects, processes, and behaviour are coherent with the pursuit of landscape quality in accordance with sustainable development.

Table 2.1 Requirements of an environmental indicator at a common international level. (Source: OECD 2003)

Relevance

An environmental indicator must:

1. provide a representative image of environmental conditions, the pressure on the environment and the social response;
2. be simple, easy to interpret and able to show trends in time;
3. be sensitive to changes in the environment and interrelated human activities;
4. provide a basis for international comparison;
5. be useable at both a national level and in issues of regional interest;
6. be associated with a threshold or value of reference so the user can rapidly assess the determined level.

Analytical soundness

An environmental indicator must:

1. be well defined from a theoretical point of view and in technical terms;
2. be based on international standards and be validated at an international level;
3. be ready for interfacing with economic models and territorial IT systems.

Measurability

The data necessary for the construction of the indicator must be:

1. already available or obtainable at a reasonable cost/benefit;
2. suitably documented and of a certifiable quality;
3. revised at regular intervals in accordance with validation procedures.

2.1.2 Environmental Indicator Systems

2.1.2.1 The DPSIR Model

Alone, an indicator provides little information unless it is associated with a system of indicators, able to provide systematic information for the purpose of assessment.

A system of indicators consists of several indicators correlated from a logical and functional point of view, able to describe and provide information on several phenomena associated with each other, or which need to be interpreted in a coordinated way.

One consolidated instrument for the integrated analysis of the social-economic and environmental aspects in the field of sustainability assessment is the system of environmental indicators known as the DPSIR model (Driving forces, Pressures, State, Impacts and Responses), established by the Organisation for Economic Co-operation and Development in the early 1990s (OECD 1993), and acknowledged by the European Environment Agency (EEA 1995).

In the DPSIR model, the basic idea is that the *driving forces* of the economy generate pressure on the territory in terms of consumption of resources and pollution. If this pressure exceeds the capacity of the territory in question, it is considered unsustainable and the direct effect will be a deterioration in the state of the environment in question. The impacts, which are associated with the state of the territory, concern the ultimate effects of the pressures on the environment; and are therefore related

Table 2.2 Categories of environmental indicators in the DPSIR model

Category	Description
Driving forces (D)	These constitute the basic factors that influence a range of variables pertinent to the same (for example: the number of cars per inhabitant, total industrial production)
Pressures (P)	Describes the variables that directly cause environmental problems (for example: toxic CO_2 and noise emissions from traffic; the quantity of waste produced by demolishing vehicles per year)
State (S)	The current condition of the environment (for example: the concentration of lead in urban areas; noise levels near main roads)
Impact (I)	Describes the ultimate effects of the changes in state (for example: the percentage of children who suffer from lead-induced health problems; the number of people who die of hunger due to crop loss caused by climate change)
Responses (R)	The efforts of the social system to solve the problems (for example: the percentage of cars with catalytic exhausts; the maximum levels of noise emissions allowed for cars)

to a deterioration in human health, a drop in biodiversity, and a deterioration of the landscape. These impacts are countered by the response of society and institutions administering the territory (Boeris et al. 2002).

Therefore, to be effective for territorial planning, the DPSIR model must be supported by a system of indicators that can quantify the various components to establish the specific cause/effect of environmental deterioration. These indicators are divided into the five categories shown in Table 2.2.

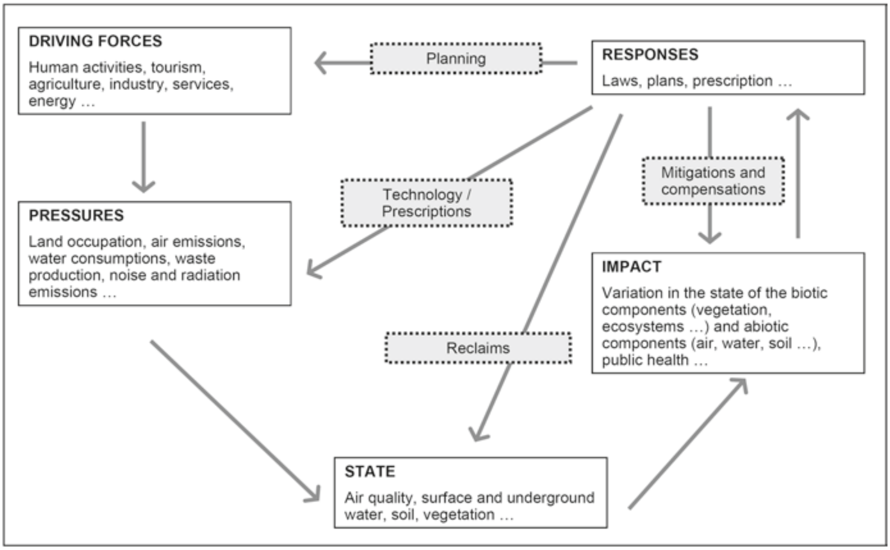

Fig. 2.1 The DPSIR model

Figure 2.1 describes the causal sequence between: anthropic actions (Driving forces and Pressures), conditions of state/environmental quality (State and Impacts) and actions taken to solve any critical situations (Responses).

Another organisation dealing with environmental indicators refers to the different functions that these can have. In particular, different types of indicators are established (EEA 2003) to answer the following questions:

- What is happening? (Type A)
- Is it relevant? (Type B)
- Are we witnessing changes? (Type C)
- Are the responses effective? (Type D)
- Does it contribute to the level of global wellbeing? (Type E)

In other words, the following five classes of environmental indicators are identified:

(a) *Descriptive indicators:* usually presented as linear diagrams that represent the trend of an environmental variable in time; normally used as indicators of state, pressure or impact;
(b) *Performance indicators:* associated with certain objective values (target), measuring the distance between the current environmental situation and the desired environmental situation; they may be indicators of state, pressure or impact;
(c) *Efficiency indicators:* these measure the efficiency of products or processes from a point of view of the consumption of resources, emissions and waste per output unit;
(d) *Policy-effectiveness indicators:* used to provide information on the relationship between the change in environmental variables and environmental policies; mainly indicators of response;
(e) *Total Welfare indicators:* specific indicators that provide information for policy decision makers on environmental, economic and social issues.

2.1.2.2 The CMEF Model

The CMEF (*Common Monitoring Evaluation Framework*) model refers to a system of assessment created by the European Union to monitor Rural Development Plans (European Commission 2006).

In particular, this system defines five categories of indicators for the assessment of the plans on the basis of the scheme shown in Fig. 2.2.

The assessment system is developed in a series of phases.

Starting with the development of a SWOT analysis to establish the strengths and weaknesses, opportunities and risks of the system, on the basis of some context indicators, we can establish the goals we wish to reach with the implementation of the plan and strategies to use. Subsequently, with reference to the measures of the action indicated in the plan, we will have to monitor the implementation through input, output, result and impact indicators. Table 2.3 shows a summary of the indicators in the CMEF model.

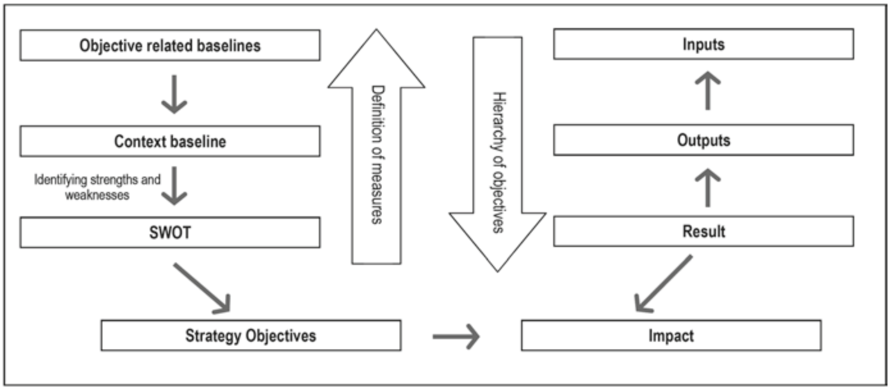

Fig. 2.2 The CMEF model. (Source: our elaboration from European Commission 2006)

Table 2.3 Categories of indicators in the CMEF model

Category	Description
Input indicators	These indicators refer to the budget and the allocation of the resources used (Ex. declared cost of each measure identified)
Output indicators	These indicators are used to measure the actions carried out directly as part of the plan. These activities are the first step towards the implementation of strategies for reaching the envisaged goals, and are measured in physical or monetary units (Ex. number of training courses held, number of companies that received incentives …)
Result indicators	These indicators measure the immediate effects of the planned interventions and provide information on the changes implemented (Ex. number of jobs created)
Indicators of impact	The indicators of impact refer to the benefits of the programme. They do not only consider the direct beneficiaries, but include the entire area affected by the plan (Ex. increase in employment in rural areas, growth of productivity in the farming sector)
Basic indicators	These indicators are useful for the preliminary analysis of the plan and are divided into the following categories: • objective indicators (used as a reference to assess the impact of the plan) • context indicators (provide information on the general state of the system for which the plan was drawn up)

2.1.3 Indicators and Indexes

One indicator alone cannot express the complexity of the system being observed, but it is just as true to say that a system of partial and extremely incoherent indicators can be an obstacle in the assessment procedure.

Therefore, synthetic indexes can be defined, based on a combination of the information with reference to a multitude of indicators, able to express a value which represents the phenomenon being studied.

The importance of defining synthetic indexes through the aggregation of several different indicators (even with the loss of information as a result of said aggregation), is clearly expressed by all experts in strategic assessment who must, due to the nature of these procedures, be able to make judgements on compatibility very quickly (Jesinghaus 2000).

The correct procedure for establishing synthetic indexes that refer to a determined situation subject to study is based on the following steps:

- Identification of the goals we wish to reach with the project being assessed;
- Definition of the alternatives and future scenarios the assessment must refer to;
- Definition of the useful and available partial indicators the aggregation should be based on;
- Definition of the operational mathematical procedure for the partial data combination;
- Definition of the methods of representation for transferring and applying the results.

The main methodological reference for the aggregation of a system of partial indicators in an overall index is the approach based on the *performance index*. Particularly, the Policy Performance Index was drawn up by Jochen Jesinghaus in 1999 during research for the JRC (Joint Research Centre of the European Commission) to integrate classic social-economic indicators (GNP, inflation rate, employment) with new elements (in particular concerning environmental policies) in the assessment of the success or failure of certain policies (JRC 2009).

Let's look at the pie chart in Fig. 2.3. As we can see, there are several indicators that can be used as a starting point for the analysis, divided into three main categories:

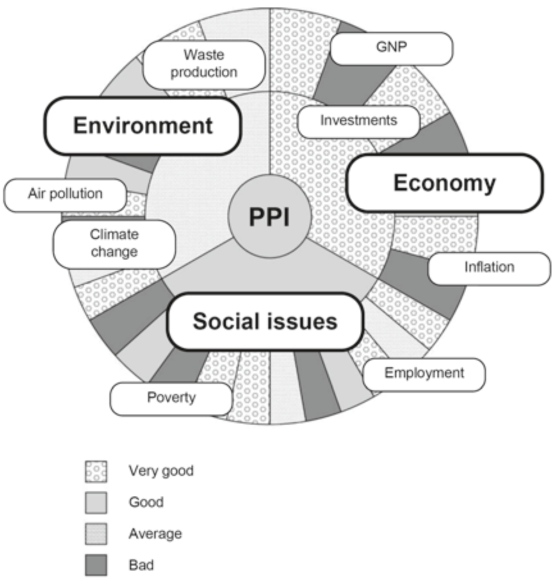

Fig. 2.3 Example of representation of the *Policy Performance Index*. (Source: Jesinghaus 1999, reworking)

- an *Environmental index*, consisting of many indicators in the environmental field (waste produced, atmospheric emissions, etc.);
- a *Social index*, consisting of indicators on social matters (the quality of medical healthcare services, distribution of wealth, poverty, etc.);
- an *Economic index*, which consists of typical economic indicators (GNP, inflation, investments, etc.).

The three partial indexes are combined in one single Policy Performance Index (PPI) and shown in a pie chart with three concentric circles. The three circles contain:

1. the global PPI in the centre;
2. the three sub-indexes for Environment, Society and Economy in middle circle;
3. the simple indicators in the outer circle, where the size of each segment indicates the effect on the overall assessment.

When considering indicators and synthetic indexes, it is fundamental to reflect on the basic data on which the assessment is developed. One very useful concept consist of the "information pyramid" (or "iceberg information") (Fig. 2.4) which highlights the essentiality of so-called "invisible work", in other words the technical and methodological approach of research and statistics institutes, without which assessment would be impossible (Jesinghaus 1999).

We must emphasise the importance of a synthetic index when developing the assessment. This requirement can be attributed to various reasons. First and fore-

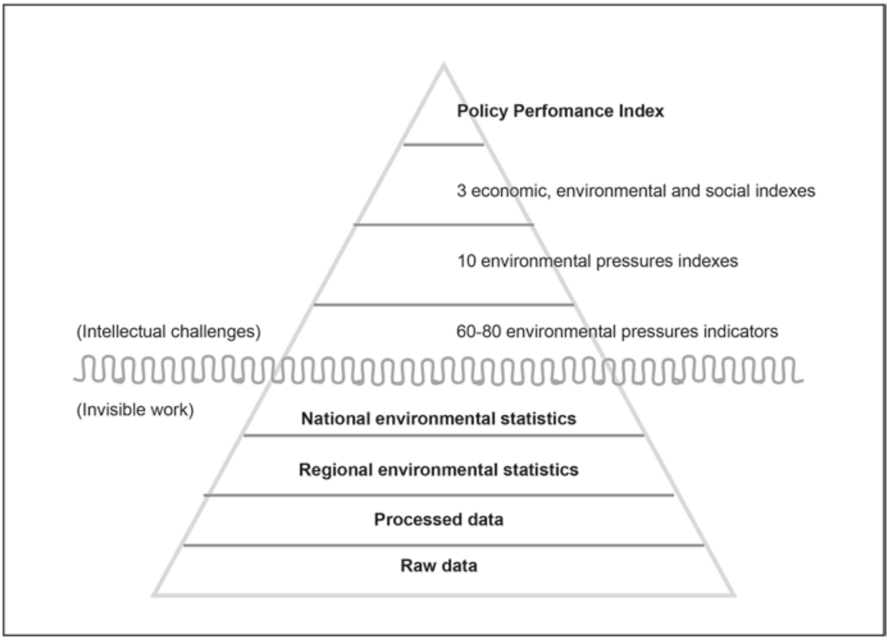

Fig. 2.4 The information pyramid. (Source: our elaboration of Jesinghaus 1999)

most policy decision makers require a further summary of environmental information, for fast and immediate interpretation, to base their decisions on (Giovanelli et al. 2000). In fact, it is a lot better for policy decision makers to have, for example, an index on the quality of water, rather than a series of indicators on the specific physical-chemical characteristics of water resources. Furthermore, with particular reference to landscape assessment, the use of a synthetic index able to provide information on the state of a certain landscape system is of primary importance in more extensive assessment contexts, in which the landscape is one of the components of sustainability. The landscape index can therefore be integrated and combined with the indexes of other components of the system to create an index of overall sustainability.

The last important element in the construction of a system of indicators and indexes that represent the real situation of the territory in question is the weighting of indicators. In fact, various indicators can contribute with varying importance to the definition of a single quality, or have a different affect in the goals-criteria system of a decision-making process. With this in mind, we should remember the role that derived statistics techniques such as multiple regression analysis and multivariation analysis, or methods such as the *Delphy* method have played in defining the importance of criteria or indicators in an assessment procedure.

2.1.4 Fields of Application

The need for integrated use of the indicators stems from a considerable growth of interest in the field of government instruments on environmental quality, and economic and social instruments in general.

The context of the theme is related to decision-making system and its various aspects pursuant to the existing situation (in particular decisions concerning administrative aspects of the organisations involved) and those of the future (decisions on plans, programmes and projects).

We must also consider the progressive organization and the complexity of the references, which include consolidated tools (system of standards and controls), others being defined (environmental reporting for example), other tools recently adopted as a result of legislation within which there is ample room for improvement (such as those for Strategic Environmental Assessment or for the assessment of environmental damage).

Some tools apply to future forecasts for the purpose of prevention, others to the current situation again for the purpose of prevention, some favour the support of decisions, others put the emphasis on evaluation.

Figure 2.5 shows the overall picture on the use of indicators, while Table 2.4 provides a description of the main existing fields of application.

The last entry on environmental indicators refers to the problem of the scale of reference. The theme of the scale concerns both the time coordinates and the geographical coordinates of the indicator.

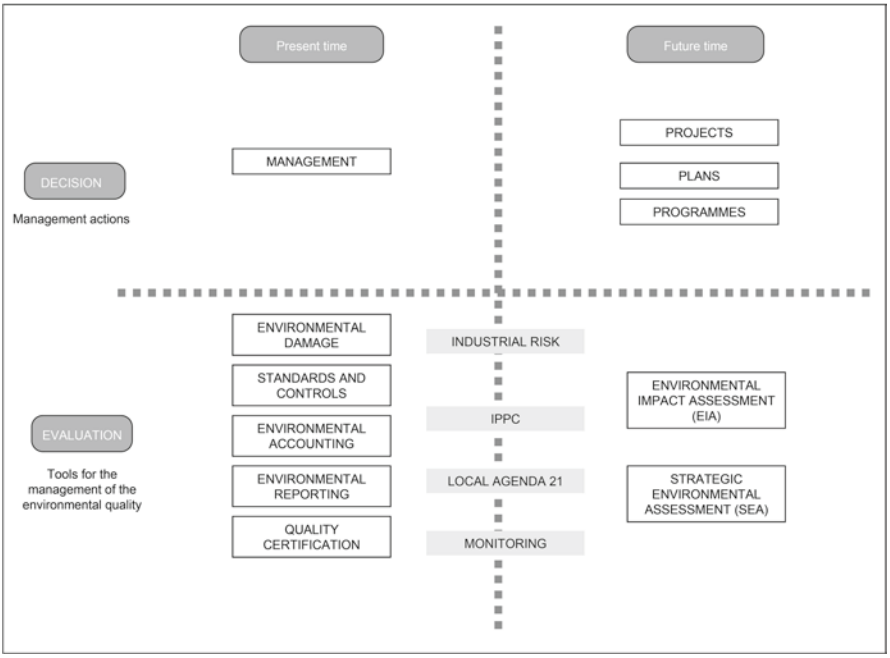

Fig. 2.5 Chart showing the main government instruments that envisage the use of environmental indicators. (Source: Malcevschi 2004, reworking)

As for the time scale, the indicators may be *synchronous* if they refer to an instant in time, or *diachronic* if they refer to variations in conditions and behaviour. The second type is mostly used in relation to landscape, as we are referring to a process in which elements and structures change along a time line.

The theme of the territorial scale of reference is more interesting however. The problem of scale is particularly important for analyses such as those considered from the time that affects the successful outcome of the assessment. The choice of the territorial scale of reference in fact, is closely associated with the problem of the availability of basic data for indicator calculation (assessment done using an analysis scale at a regional level, for example, cannot be based on national data as the transformations in question would be illegible).

Most of the indicators used by international organisations on sustainable development take the national scale as a reference. However, for landscape, as established by the European Convention, the indicators can refer to both the national scale and subnational scales (regional and local).

In the case of the present study, we will adopt an inter-scale approach as far as possible, without using one specific scale and using the regional level as reference. This level in fact is the one used as reference for landscape and territorial policies in general.

Table 2.4 Use of environmental indicators in various fields of application. (Source: Malcevschi 2004, reworking)

Decision-making instrument	Use of environmental indicators
Command & Control	• To assess the level of environmental quality • To establish legislative standards by acknowledging thresholds beyond which the value of an indicator becomes a potential risk
Environmental Impact Assessment (EIA)	• To describe the persistent environmental situation at the sources of impact generated by the project • To forecast and estimate impacts • To control the evolution of efficiency and stability of the work and the situation of the environmental system in question
Strategic Environmental Assessment (SEA)	• To emphasize the environmental and territorial characteristics of the area affected by the plan • To make the specific goals of the plan measurable • To assess the major effects deriving from the actions of the plan • To monitor the degree of implementation of the plan and the situation of the environment in question
Environmental reporting	• To describe the state of the environmental system • To report on the conditions of quality and criticality of the environment to help in decision-making processes
Corporate environmental communication	• To describe the level of interaction between the company and the environment • To measure the level of response in the field of the company to improve environmental performance
Sustainable development	• To provide a solid base for decision-making processes on all levels • To obtain a diagnostic outline of the territory in question • To monitor and verify the goals of sustainability are reached
Environmental certification	• To assess the environmental performance of the certified organisation
Management Plans	• To monitor systematically the results of the plan in time

2.2 The Presentation of Indicators

2.2.1 Types of Existing Tables

The use of indicators and systems of indicators for a specific assessment requires that the same are presented in a clear and effective way. The documentation on indicators contains various types of models for the presentation of the single indicators.

A first, very simple type, refers to the presentation of the fundamental indicator information, such as the definition, the formula for calculation, and some other essential data.

Examples of this type are provided in the list of indicators drawn up by the Association of Environmental Analysts (AAA 1999) or other international reports (Esty et al. 2005, 2006).

A second, slightly more complex type, involves presenting a table, which is concise and easy to consult, containing the definition, formula and description of the process. This type is used in the Mediterranean Action Plan (Plan Bleu 2006) or OECD (2004).

A third type, more complete and structured, refers to models in which the tables for the presentation of the indicators contain the definition, the standards of references and an indication of the thresholds of reference for the assessment, the method of calculation, the data specifications, any uncertainty associated with the indicator, future work and other general data (including, among other things, the category of the DPSIR model).

An example of this kind of table is used for the indicators monitored by EEA (2009); in Italy we can also refer to the indicators used by Piedmont Regional Agency for the Protection of the Environment (2008) (APAT 2006; Nappi et al. 2007). Furthermore, the system of landscape indicators proposed by Vallega (2008) also refers to this type of presentation.

Finally, a useful and complete form of presentation, in line with the above but specifically drawn up for landscape assessment, is proposed by Malcevschi and Poli (2008). The presentation contains the description of the indicator, the landscape aims, the type of indicator (simple or complex, qualitative or quantitative), the variables in the same, the indications relevant to the work in which the indicator was used, the unit of measure, the time and territorial scale, the characteristics of use of the indicator, the availability of initial data and the method to use for presenting the results.

The last model is the one used to draw up most of the tables for the presentation of the indicators in the study.

2.2.2 Proposed Table for Landscape Indicators System

The proposed table (Table 2.5) is the result of a summary done on the basis of the study, and the comparison and analysis of existing documentation at a national and international level. In fact, in order to establish a common model for the presentation of the indicators in this study, we initially referred to various tables in existing documentation.

Once the most suitable type was found, we proceeded by testing the operative capacity, verifying the applicability of the elements of the table and proposing some others.

The result of these operations resulted in the table for the presentation of the indicators shown below.

- *Indicator:* name of the indicator;
- *Definition:* a short definition of the indicator;
- *Description:* describes the indicator and presents the methods and formulas for calculating the same;

- *Category:* the indicator category of those identified in the present study (ecology, perception, soil uses, cultural heritage, economy);
- *Aims pursuant to landscape:* the aims of the indicator in landscape study; the indicator can be used to establish elements and processes of interest for landscape, identify or assess the same;
- *Status/Process:* the theme concerns the time and geographical coordinates of reference for the indicator; the indicator can in fact refer to an instant in time (State) or temporal variations in conditions and behaviour (Process);
- *DPSIR category:* the category in the DPSIR model (Driving forces-Pressures-State-Impact-Responses);
- *Typology:* indicates whether the indicator is a simple indicator or a complex index, that is the result of the aggregation of several indicators; in this case the variables of the index and the aggregation procedure used must be specified;
- *Unit of measure:* the unit of measure that describes the indicator;
- *Territorial scale:* the geographical scale of reference; as the framework of indicators proposed refers to the European Landscape Convention, the geographical scale encompasses the local and regional scales;
- *Time scale:* the most suitable period of time the indicator should refer to;
- *Characteristics of use:* specified in fields of application in which the indicator can be used (technical-scientific analysis, monitoring, plans, …);
- *Availability of data source:* the sources of the data on which the indicator calculation is based;
- *Method of representation:* the ways in which the processes associated with the indicator can be represented (theme maps, temporal diagrams, …);
- *Fields/work in which it was used:* the fields of application in which the indicator was used; whenever possible, indicate the bibliographic reference of the work in which the indicator was used and/or applied.

Table 2.5 Indicators table

Indicator
Definition
Description
Category
Aims pursuant to landscape
Status/Process
DPSIR category
Typology
Component variables (if index)
Unit of measure
Territorial scale of reference
Time scale of reference
Characteristics of use
Availability of data source
Method of representation
Other explanatory notes
Fields/work in which it was used

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ESL European Statistical Laboratory. http://esl.jrc.it/
European Commission. http://ec.europa.eu/index_en.htm
Eurostat. http://www. epp.eurostat.ec.europa.eu
IUCN International Union for Conservation of Nature. http://www.iucn.org/about/index.cfm
Observatori del Paisatge de Catalunya. http://www.catpaisatge.net/cat/index.php
OECD Organization for Economic Co-operation and Development. http://www.oecd.org/
SINAnet Sistema Informativo Nazionale Ambientale. http://www.sinanet.anpa.it
UN United Nations Department of Economic and Social Affairs Division for Sustainable Development. http://www.un.org/esa/sustdev
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