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Does research applying the DPSIR framework support decision making?

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ABSTRACT

The Driver-Pressure-State-Impact-Response (DPSIR) framework was developed in the late 1990s to structure and organize indicators in a meaningful way. Since then, the framework has increasingly been applied in research projects with the aim of supporting decision making. A number of attributes of the framework regarding structuring and communication issues in research further strengthen its original purpose of bridging the science policy gap. We reviewed several studies that were mainly concerned with criticism and drawbacks of the DPSIR framework. Based on these studies and our own experiences in applying the DPSIR framework in an EU project to develop a decision support tool, we developed two criteria that we believe are crucial for policy relevant research: (a) the development of conceptual models integrating knowledge from different disciplines, specialists and policy makers, as well as those affected by their decisions; and (b) the potential to explain the results and analysis of research to different disciplines, specialists, stakeholders and the public and to demonstrate alternatives and provide decision options. We analyzed 21 studies using the DPSIR framework with regard to their relevance for decision making. We analyzed the definitions of the five DPSIR elements and whether specific end users were addressed in the respective studies. We found that in many studies, the DPSIR elements were defined in literature review or by researchers and that only a few studies targeted specific government authorities as users of research results. Eight out of 21 studies applied transdisciplinary research concepts and integrated broad ranges of stakeholder opinions and values into the research. Nine out of 21 studies presented alternative outcomes to decision makers and used the valuation of these outcomes by stakeholders to add further support to the decision-making process. The different positive and negative implications of the DPSIR framework are discussed with reference to research that supports policy making. Finally, we conclude that studies employing DPSIR may provide effective solutions for "real world problems" by taking into account additional criteria based on knowledge integration, stakeholder involvement and the provision of alternatives. Therefore, DPSIR is a useful tool to support decision making by means of showing solid evidence with alternatives and decision options, rather than by presenting predetermined solutions.

Introduction

The Driver-Pressure-State-Impact-Response (DPSIR) framework was developed in the late 1990s and proposed by the Organisation of Economic Co-operation and Development (OECD, 2003) as a means of structuring and organizing indicators in a way that is meaningful to decision makers. Built on previous environmental frameworks, such as the Pressure-State-Response (PSR) (OECD, 1993) and the Driver-State-Response (DSR) (UN, 1996), DPSIR was adopted as a conceptual framework by the European Environmental Agency (EEA) in 1995 (Gabrielson and Bosch, 2003). DPSIR was promoted to show the cause–effect relationships between environmental and human systems. The framework was introduced in a report by Smeets and Weterings (1999) *to help policy makers to understand the meaning of the information in indicator reports*.

Drivers, which may be social, economic or environmental developments, exert *Pressures* on a certain environment. As a result of these *Pressures*, the *State* of the environment changes. This then leads to an *Impact* (social, economic or environmental), which may lead to a societal *Response*. The response may feed back to *Drivers*, *Pressures*, *States* or *Impacts* (Smeets and Weterings, 1999). For example, if a policy is introduced to subsidize bio-energy production (*Driver*) farmers begin cultivating large areas of bio-energy crops, which leads to *Pressure* on the land. The land use changes from food production to bio-energy crop production; thus, the *State* of land, the environment and outcome changes to being characterized by lower food production and higher fertilizer use. The

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change of the *State* leads to *Impacts* in the areas of food security, health and demography that need to be assessed. A way to address undesired *Impacts* is to create, as a *Response,* incentives for food production.

Recently, DPSIR has been used for interdisciplinary indicator development, model conceptualization and the structuring of policy relevant research (Svarstad et al., 2008). The framework has been applied in an increasing number of research projects funded by the European Union with the aim of supporting decision making (Karageorgis et al., 2005; Helming et al., 2011a). Kristensen (2003) stated that DPSIR could be used as an entry point, alongside the questions of decision makers, to develop indicator sets. He noted that DPSIR may be considered as a tool for structuring information and for demonstrating causal links between environmental indicators to policy makers. Lundberg (2005) further noted that the DPSIR framework is an example of the integration of knowledge from several disciplines, and it is a way of explaining cause–effect relationships between the environment and socio-economic factors.

Decision making should be based upon the best available evidence from a wide range of sources, and a wide range of key stakeholders should be involved at an early stage and throughout a policy's development (De Smedt, 2010). All relevant evidence should be available in an accessible and meaningful form. The role of the researcher is to provide the best available evidence to the decision maker, to help monitor existing policies and to react to unexpected events (Bullock et al., 2001).

The question we pose for this paper is whether and under which conditions the application of DPSIR in research studies can support decision making. We first present a literature review depicting the current state of the DPSIR framework employed in research projects. We comparatively analyzed 21 studies that applied the DPSIR framework according to the criteria we developed. In the next section, we review various studies that are mainly concerned with criticism and drawbacks of the DPSIR framework. Thereafter, we discuss our experience of the DPSIR framework as it was applied in the EU project SENSOR,[1] in which three of the authors of this paper were involved in research and coordination activities.

These reviews, the study by Lundberg (2005) and our own experiences provided a basis for us to develop criteria for decision supporting research.

State of the art

The DPSIR framework and its application in research

After its adoption by the EEA in 1995, DPSIR became popular in studies involving the management of nutrient fluxes in marine environments (Turner et al., 1996; Newton et al., 2003; Scheren et al., 2004), integrated coastal management (Bowen and Riley, 2003), development in catchment areas (Cave et al., 2003), and offshore wind power generation (Elliot, 2002). The framework has been applied worldwide, ranging from global (Odermatt, 2004) to national scales. Additionally, some studies have been carried out on a catchment scale (Karageorgis et al., 2005; Pirrone et al., 2005) or on a regional scale (Holman et al., 2005). DPSIR has been used for parallel assessments dealing with environmental and socio-economic perspectives and impacts (Odermatt, 2004; Agyemang et al., 2007; Mangi et al., 2007; Giupponi et al., 2006). In addition, an increase in research on sustainable development broadened the use of DPSIR because it enables integrative, multidimensional assessments (Pintér et al., 2005). A number of DPSIR studies have dealt with the agricultural sector and rural areas (e.g., Odermatt, 2004; Pirrone et al., 2005; Borja et al., 2006).

The DPSIR framework identifies and visualizes, in a simplified way, cause and effect relationships between factors in society and the environment (Smaling and Dixon, 2006). It supports project-related structuring and comprehension issues. Furthermore, it can be used as a communication tool between researchers (including those from different disciplines), policy makers, and stakeholders (Svarstad et al., 2008). DPSIR is described as a reliable scientific tool for tackling environmental issues (Karageorgis et al., 2005) and as a starting point for both scenario analysis (Pirrone et al., 2005) and participatory scenario analysis (Ledoux et al., 2005). Recent studies have indicated that stakeholder values are the key to structured policy making with public involvement (Lorenzoni et al., 2000; Gregory et al., 2001). In real terms, Lorenzoni et al. (2000) found for a case study in East Anglia that indicators that had been designed to meet the practical needs of stakeholders worked best.

Bidone and Lacerda (2004) applied the DPSIR framework to integrate natural and socio-economic indicators in the Guanabara Bay basin in Brazil. They evaluated the losses and benefits from policies by including cost-benefit analysis in their framework.

In 2005, Gisladottir and Stocking (2005) published a study using DPSIR as a conceptual framework model, showing how land degradation control could be made more effective. They noted that the inclusion of processes and linkages into a conceptual model using the DPSIR framework helped to interrelate impacts and societal responses. The assessment of these impacts and responses resulted directly in the development of degradation control measures.

An outstanding example of stakeholder integration is a study carried out by Chung and Lee (2009), in which they developed an alternative evaluation index (AEI) concerning watershed management options. The watershed management alternatives were subsequently ranked by residents of the region. This AEI based on hydrological modeling additionally reflects residents' demands on watershed management objectives. This offers flexibility to the decision maker through the presentation of alternatives and through obtaining residents' consensus for potential planning activities.

Agyemang et al. (2007) used DPSIR successfully in Ghana to organize complex environmental information and present it to policy makers. The authors reported that despite its use in Europe, DPSIR is not well known in developing countries. The project team began with the development of the *State*. The state of the environment was described (observed land use and land cover change) through remote sensing, Landsat TM imagery and by testing ground truth. The remaining elements of the framework were collected by three participatory research methods. As a first step, the team used DPSIR to design the project, and then their research results were overlaid on this structure. The *Pressures* were defined by the key informants as being mostly small-scale legal underground mining, illegal surface mining, quarrying and burning of scrub. The main driving forces for the major impacts on the environment were: national policies for economic transformation, population growth, migration, poverty, and land tenure systems. *Impacts* were defined as physical impacts from vegetation loss, cross-cultural tensions, pressures on women, health risks and reduction in living standards. The research team offered four different policy options to the participants with regard to improving the state of the envi-

[1] SENSOR was an integrated project funded by the 6th Framework Programme of the European Commission to develop "sustainability impact assessment tools for environmental, social and economic effects on multifunctional land use in European regions". SENSOR, a four-year project, brought together teams of researchers from 36 institutes in 15 European countries, as well as China, Brazil, Argentina and Uruguay. The aim was to develop Sustainability Impact Assessment Tools (SIAT) that support *ex ante* assessment of new policies on six land use sectors: agriculture, forestry, nature conservation, transport infrastructure, energy and tourism. By integrating cross-sector knowledge at a European level, the project provided decision makers with scientifically sound information on regional impacts of land use changes and policy effects on sustainable development (SENSOR, 2009).

ronment. These options were defined as: *business as usual*, *driving force reduction*, *preservation and conservation practices* and, *impact mitigation*. Preferences among the scenarios differed between the participatory groups, though the majority of the participants agreed that the ongoing deterioration of nature required policy options to improve the state of the environment and to halt the decline of their living standards. Thus, business as usual (i.e., the assumption that people will somehow adapt to the changing environmental and social circumstances) was predominantly rejected as unacceptable. The authors concluded that this application showed that use of the DPSIR framework reduced the complexity of indicators and, thus, made the interrelations and connections between them understandable.

Roura-Pascual et al. (2009) studied causal chain relationships between natural conditions, human activities and the spread of invasive species. At a workshop at local scale, participants described each component of the DPSIR framework and identified the respective linkages. Workshops were held in various regions with distinct conditions. The DPSIR framework helped to elaborate a conceptual model understanding the invasion of species in these regions. Subsequently, management options were discussed on the basis of these findings.

According to the definition and the intention of the EEA (Smeets and Weterings, 1999), one important purpose of the DPSIR framework is to overcome the communication gap between scientific systems with political systems and the public. Thus, indicators classified according to the DPSIR framework should enhance communication between scientists, politicians, and the public about environmental developments and issues.

DPSIR has been used with the objectives of identifying policy solutions (Pirrone et al., 2005), linking EU policies to issues of biodiversity (Kuldna et al., 2009), and of analyzing socio-economic and environmental issues with regard to policy responses (Mangi et al., 2007). Nilsson et al. (2009) used the DPSIR as a basis for a framework to follow-up Strategic Environmental Assessment (SEA). SEA runs in parallel with the decision making process and assesses policies in respect to their impacts on the environment or on Sustainable Development. Observing that methodological frameworks to engage with SEA follow-ups are fairly missing the authors developed a framework based on programme theory framework and DPSIR.

Criticism and drawbacks of the DPSIR framework

Criticism of the framework mainly refers to its implicit hierarchical structure. Carr et al. (2007) stated that this structure causes a hierarchy of elements and, therefore, also of actors. Individuals and groups who are actually affected by social and environmental changes have only the potential to address impacts. Svarstad et al. (2008) made the criticism that the conventional use of the DPSIR approach implies the existence of neutral knowledge of environmental interrelationships. Thus, DPSIR excludes normative perspectives and concerns. DPSIR has also been criticized for focusing on causal chain, one-to-one relationships, rather than addressing complex interrelationships, which are found in reality (Niemeijer and De Groot, 2008).

Niemeijer and De Groot (2008) pointed out the importance of the DPSIR framework with regard to causality. The approach is useful because the connections between the identified and selected indicators describe causality. Thus, the authors were of the opinion that the approach was an effective means of structuring and, thus, simplifying the causalities of environmental issues. The approach has a valuable potential for serving as an information basis for policy makers. Furthermore, it possesses the characteristic of being able to implement standardized assessments with multidisciplinary and interdisciplinary qualities.

Nevertheless, Niemeijer and De Groot (2008) recognized a structural deficiency in this approach. Their criticism was that the DPSIR framework implies single and unidirectional causalities between indicators. To improve DPSIR's ability to strengthen conceptual model development, Niemeijer and De Groot (2008) suggested an enhanced approach that actually focuses on the interconnections between different indicators. To achieve this, the authors replaced the unidirectional causal chains with multiple causal networks, which should also provide a more reliable basis for indicator selection.

The "enhanced" DPSIR framework devised by Niemeijer and De Groot (2008) helped to identify and specify indicators and reduced their number. Furthermore, this would enable policy makers and managers to determine precise and, thus, effective starting points for monitoring. Finally, the enhanced framework was useful for integrating both cross-sectoral and environmental issues. This led to clear proposals before political decision making took place. In several studies, causal webs were transformed into conceptual models to incorporate research objectives (e.g., Haberl et al., 2009; Bianet Jago-on et al., 2008; Holman et al., 2008; Kuldna et al., 2009).

Similarly, Carr et al. (2007) characterized the DPSIR framework's structure as deficient because it does not deal with different level drivers and responses. In most studies, global or at least national level drivers and response actions are analyzed thereby disregarding local responses, or responses of certain social groups, which influence impacts but do not influence drivers or pressures. This marginalization of the aggregated practices of local groups and individuals inevitably leads to sub-optimal outcomes of sustainability development initiatives. Thus, the DPSIR's structure marginalizes aggregated and informal responses on *Pressures* and *Drivers* and favors the perspectives of a limited number of organizations and agencies that act at the global or national level. Analysis of problems and potential responses to *Drivers* and *Pressures* rests in the hands of a *policy network*, which consists of international, regional or national experts, organizations and authorities. On such a basis, knowledge construction and policy making may lead to unintended and negative consequences for development. Moreover, there is a tendency for biased perspectives and practices to become self-referential and self-reproducing. Thus, local and alternative views and knowledge remain unconsidered. Consequently, potential policy options are marginalized, and the existing hierarchies are reproduced automatically (Carr et al., 2007).

Carr et al. (2007) did not propose a solution for the shortcomings of DPSIR that they described; rather, the authors asserted that the addition of a further element would not be sufficient to repair its structural defects. However, they assumed that another tool could be developed to correct the unequal power hierarchy itself and not merely its consequences. Thus, assessments applying the DPSIR framework would be possible if the impacts of aggregated and informal responses on driving forces and pressures were integrated structurally. Nevertheless, Carr et al. (2007) also pointed out that the DPSIR framework was useful for local-scale analysis if implemented at that level. Local interests, concerns, positions, developments and their connections with environmental changes could then be assessed realistically.

Svarstad et al. (2008) applied a discourse perspective[2] to analyze the DPSIR framework. They based their analysis on existing work by Adger et al. (2001) and Svarstad (2002, 2004) on the issue of biodiversity. The researchers criticized that the conventional use of the DPSIR approach implied the existence of neutral knowledge

[2] Svarstad et al. (2008) applied the "discourse analysis as one way to understand shared ways of social phenomena. That is, discourses constitute systems of knowledge and belief".

of environmental interrelationships. Thus, DPSIR excludes certain perspectives and concerns. This exclusion leads to a discourse-selective understanding of issues.

To examine their hypothesis, Svarstad et al. (2008) used a perspective that combined the assumptions of social constructivism and discourse analysis. The authors defined four different types of discourses: preservationist, win-win type, traditionalist type and promethean type. Three aspects were used to characterize these types: the degree of conservation or protection of biodiversity, the degree of integration of the interests of local people and the grade of partnership with local or external actors.

The preservationist discourse sees the enforcement of law that protects biodiversity as the only possible response option. Industrialization, urbanization, economic and extractive activity are considered to be the main pressures. Population growth and economic development are identified as the major driving forces. The authors concluded that the DPSIR framework may be a useful tool to analyze the different issues of a preservationist discourse.

The win–win discourse type also defines the protection of habitat and species as the main issues and concerns. However, this impact category additionally considers social and economic effects because disregard of these effects could cause harmful behavior, which again could lead to environmental degradation. Measures of protection are considered to be the most important responses. However, these measures should also address the social and economic concerns of local people. Thus, their implementation is seen as a common goal. Drivers and pressures are similar to those in the preservationist discourse, but driving forces that cause social pressures are also considered. Svarstad et al. (2008) noted that the conventional application of the DPSIR approach may, however, ignore social concerns.

The traditionalist discourse is focused on local actors and rejects interventions by external actors in environmental and natural resource issues. Consequently, impacts on local groups are of central importance. Policy options that focus on social and economic concerns have to be implemented locally. The conventional application of DPSIR most likely does not allow for the concerns of many people to be taken into account with perceptions of a traditionalist discourse (Svarstad et al., 2008).

The promethean discourse type considers changes in the environmental state as unimportant. Driving forces or pressures that impact biodiversity do not fit into its perception, and any nature conservation option is regarded as causing problems to people. Consequently, activities (*Responses*) related to nature conservation are rejected. Svarstad et al. (2008) concluded that the conventional application of the DPSIR framework is not able to represent the promethean discourse type.

Thus, the conventional use of the DPSIR approach only satisfies the preservationist discourse and, in part, the win–win discourse. Thus, the framework favors or excludes certain perspectives, concerns and affected groups, i.e., it leads to a discourse-selective understanding of issues. Research results are considered to be biased and irrelevant by actors whose concerns, opinions or knowledge are ignored. Svarstad et al. (2008) called for further research to incorporate social and economic concerns into the framework, in addition to environmental concerns. Svarstad et al. (2008) proposed that researchers may base their research on "various narratives" allowing for various discourses of stakeholders.

Our experience in applying the DPSIR framework

SENSOR was designed to develop tools for a "sustainability impact assessment of the environmental, social and economic effects on multifunctional land use in European regions" (Helming et al., 2011a). The scope and aim of the project were predefined by the research funding directorate in the European Commission. SENSOR followed the EU impact assessment guidelines introduced in 2002 (CEC, 2005) (Tscherning et al., 2008), representing a formal procedure for analyzing potential impacts of policies before their implementation. The objective of SENSOR was to link policy options to land use change and its environmental, social and economic impacts. SENSOR research results had to be translated into an information format for policy support. To satisfy the demands of producing policy relevant results, policy makers participated and were consulted during the entire project duration (Thiel, 2009). At an early stage, it became clear to us that decision makers did not want *Responses* to be dictated suggested by the research; rather they preferred a large number of scenarios for cause–effect chain relationships leading to potential decision options from which they could choose. These options needed to show potential future land uses and their respective impacts on sustainable development in Europe.

The DPSIR framework was applied to structure the research in SENSOR. DPSIR was chosen because of its proven capability in the context of describing linkages between human pressures and environmental issues and its usefulness in multidisciplinary tasks. Land use change was defined as a *Pressure* that was influenced by two sets of *Drivers*: future socio-economic trends, including technological development, and policy drivers, which were to be assessed. As policy drivers, a number of policy scenarios were defined by SENSOR researchers and decision makers together. The role of the *State* was filled by more than thirty environmental, social and economic indicators that were related to land use changes and provided an estimation of impacts on land use. This large number of indicators was aggregated into nine categories of land use functions (Perez-Soba et al., 2008) exhibiting changes induced by land use policy. The concept of land use functions was derived from the ecosystem service concept (MA, 2003) and further adapted to the case of land use (Schößer et al., 2010). Alternative policy outcomes (*Response* options) could be compared in a way that was comprehensive and readily interpretable by stakeholders (Helming et al., 2011a). One of the SENSOR scenarios settings addressed the reform of the Common Agricultural Policy (CAP): complete discontinuation of both agricultural market support and direct farm income support was compared to a baseline scenario (no change in CAP) for the target year of 2025 (Helming et al., 2011b). Each scenario led to different shares of land use in Europe. Based on the DPSIR framework, the land use change was linked to indicators (social, economic and environmental) to obtain the impacts. The resulting scenarios and their impacts were discussed and evaluated by experts and decision-makers at a sub-national scale. We observed that the DPSIR framework created a common basis for participating researchers (approximately 80, from different countries and disciplines) and stakeholders (policy makers, desk officers from environmental, agriculture, rural development, research backgrounds) during the whole duration of the project (four years). Through the integration of knowledge from experts at the sub-national level, region-specific impacts and outcomes of political decisions could be presented. The framework offered the potential to provide a variety of decision options to policy-makers that were comparable because of its similar indicator base. Through the use of the DPSIR framework, a common understanding between very contrasting groups of stakeholders could be created, and consequently, a large amount of stakeholder knowledge, as well as validation by stakeholders could be integrated into decision support. Through the combination of model-based results with stakeholder knowledge, the SENSOR consortium was able to fine-tune scenarios at a sub-national level. This additionally augmented the acceptance of the project outcomes at a sub-national level (Helming et al., 2011b; Morris et al., 2011).

Development of criteria for decision-supportive research employing the DPSIR framework

Lundberg (2005) characterized relationships and functions between the sciences, politics and the public. According to Lundberg, the task of the sciences is to identify relevant environmental indicators thereby enabling an effective monitoring system to be established. To achieve this, function-relevant data must be handled effectively to link them with management structures and processes. Effective monitoring keeps policy makers and management informed about connected environmental developments and enables scientists and policy makers to react to unexpected or unintended management impacts (Lundberg, 2005).

Based on the studies used in our analysis outlining the drawbacks of the framework in relation to decision making, as well as the study by Lundberg (2005) and our own experience in applying the framework in a research project, we developed two criteria that we believe are key for policy relevant research: (a) the development of conceptual models integrating knowledge from different disciplines, specialists and policy makers and those affected by their decisions, in short "Outreach"; and (b) the potential to explain the results and analysis of research to different disciplines, specialists, stakeholders and the public and to demonstrate decision options in short "alternative Responses"

Criterion (a) "Outreach"

We assessed whether conceptual models integrating the knowledge of different disciplines and stakeholders were developed by checking the relevance of the indicator framework as a basic element for model development and the degree of stakeholder participation in the process of defining DPSIR elements. We assumed that elements defined by or in conjunction with stakeholders enabled the development of conceptual models that were related to the "real world". DPSIR applied in transdisciplinary[3] studies, resulted in the development of conceptual models with a higher degree of "real world" relevance. It was postulated that studies that defined the elements through a literature review or by the research team itself were primarily disciplinary, interdisciplinary or multidisciplinary. Studies that defined elements in consultation with private and public stakeholders and through legislation were primarily transdisciplinary. We assumed that studies using a transdisciplinary research concept were more transparent with regard to the desicion making process than studies using inter- or multidisciplinary approaches.

Criterion (b) "alternative Responses"

We assessed this criterion by checking the overall participation of stakeholders in research, the manner in which the *Response* element was presented and to whom it was addressed. We considered that studies that produced a set of alternative *Response* options and showed the potential consequences of these *Response* options were more transparent than studies resulting in only one proposition or solution. We assumed that scenario analysis depicting various storylines and integrating stakeholder views and values through participatory approaches further supported transparency and flexibility. These requisites often lead to the presentation of alternatives and decision options to the policy maker. Thus, referring to the study by Svarstad et al. (2008), we concluded that *Response* options representing "various narratives" allowing for various discourse types could lead to a greater understanding of perspectives and concerns. The inclusion of alternative views and values into decision support may prevent potential conflicts in advance.

Analysis of 21 studies applying the DPSIR framework: methods

First, we assessed 21 studies that were reported between 2003 and 2009 (Table 1) that used DPSIR and were published in peer-reviewed journals and books. We used the analysis and methods included in the 21 studies to check for trends over time. We found that the authors of the analyzed studies used DPSIR for structuring exercises, setting starting points for scenario development, as well as in participatory approaches, modeling, or indicator framework development.

Subsequently, we carried out an analysis of the methods that the authors of the 21 studies used to define the studies' DPSIR elements. Some of the DPSIR elements were defined by literature reviews or were developed by the research teams; others were defined by experts or stakeholders or through consultation with legislative entities (governmental and non-governmental).

Special emphasis was given to the *Response* element to assess the political relevance of the 21 studies.

We analyzed the *Response* element separately:

- According to the type of response, such as the implementation of effective management structures and monitoring, the enactment or enforcement of regulatory policies, the implementation of technical arrangements, the provision of public information, or private management solutions and subsidies.
- According to the target group, to which the response was addressed: government (specified[4] or non-specified), scientific community, stakeholders or the general public.

Analysis of 21 studies applying the DPSIR framework: results

The 21 studies published between 2003 and 2009 reflected diverse uses of DPSIR. Six of the 21 studies applied DPSIR in relation to participatory research and scenario development, and five studies used it to structure modeling exercises. Furthermore, DPSIR was applied in three cases for indicator framework description. It was used in Europe, Sub-Saharan Africa, Asia and Latin America or at a global level. A slight temporal trend was observed, indicating that while in earlier studies (2003–2006) DPSIR was predominantly used for water management purposes (at watershed, coastline, sea and estuarine levels), the focus changed to land degradation, farming systems, climate change and biodiversity from 2007 onwards. This determined the choice of journals in which the studies were published (Table 1).

The definitions of DPSIR elements in the analyzed studies were derived by the following methods or combinations thereof: consultation of the literature (77%), development by the research team itself (23%), expert consultation (36%), use of participatory methods that integrated relevant stakeholders (27%), and consultation of legislation (23%) (Table 2; for details concerning the *Response* element see Table 3).

These studies developed a wide variety of instruments and tools to support desicion making. The *Response* elements proposed a large diversity of actions and policies, from monitoring to technical provisions and regulatory policies. However, 64% of the *Response*

[3] Tress et al. (2004) suggested the use of the term multidisciplinary for research "of different disciplines that relate to a shared goal, but with multiple disciplinary objectives. Participants exchange knowledge, but they do not aim to cross subject boundaries in order to create new integrative knowledge." "Transdisciplinary research is defined as projects that involve academic researchers from different unrelated disciplines as well as non-academic participants, such as land managers, user groups and the general public to create new knowledge and theory and research common question". "Interdisciplinary research creates new knowledge between academic disciplines which are not related to each other".

[4] Government bodies could be considered specified if responses were directed specifically to certain policy making processes or governmental authorities.

Table 1
Studies analyzed according to the purpose of DPSIR application.

Authors	Year	Issue of Analysis	Scenario analysis	Participatory approach	Modeling	Indicator approval	Framework development	Continent
Newton et al.	2003	water management			x			EU[a]
Bidone and Lacerda	2004	water management						LA[b]
Odermatt	2004	sustainable development						global
Scheren et al.	2004	water management	x					SSA[c]
Gisladottir and Stocking	2005	degradation of land						global
Ledoux et al.	2005	water management	x	x				EU
Lundberg	2005	water management					x	EU
Pirrone et al.	2005	water management	x		x			EU
Borja et al.	2006	water management						EU
Karageorgis et al.	2006	water management		x	x			EU
Smaling and Dixon	2006	farming systems/soil						SSA
Agyemang et al.	2007	degradation of environment	x	x				SSA
Holman et al.	2008	climate change	x		x			EU
Bianet Jago-on et al.	2008	degradation of subsurface						Asia
Henriques et al.	2008	marine habitat				x		EU
Mangi et al.	2008	water management		x				SSA
Chung and Le	2009	water management	x	x	x			Asia
Haberl et al.	2009	biodiversity						EU
Kuldna et al.	2009	biodiversity						EU
Nilsson et al.	2009	SEA follow up				x	x	EU
Roura-Pascual et al.	2009	biodiversity		x		x	x	SSA

[a] European Union.
[b] Latin America.
[c] Sub-Saharan Africa.

elements were defined only by researchers without the participation of policy makers and stakeholders.

A majority (82%) of the studies targeted government authorities in general or referred to political decision making. However, less than half of them (45%) specified a political target or end-user of the research results. The results of the studies were predominantly addressed to specific government institutions alone (68%). Twelve studies addressed more than one target (55%). Only five studies were directed to private stakeholders and/or the general public (23%). More than half (68%) of the studies additionally targeted research institutes and the scientific community (68%), and four studies (18%) were directed exclusively to scientific end-users (Table 3).

Criterion (a) "Outreach"

With regard to the identification of indicators or the structuring of complex environmental information, no criticism of DPSIR was discovered in the literature. In contrast, studies included in our analysis (as examples: Odermatt, 2004; Lundberg, 2005; Karageorgis et al., 2005; Agyemang et al., 2007; Holman et al., 2008; Bianet Jago-on et al., 2008; Henriques et al., 2008; see also Table 1) explicitly concluded that the framework fulfilled the expectations concerning the structuring of complex cause–effect relationships related to environmental issues.

Eight out of 21 studies included stakeholders (e.g., laymen or experts) when defining their elements (Table 2). It was assumed that through the integration of stakeholders into the definition of

Table 2
Studies analyzed according to DPSIR element definition.

Authors	Year	Definition of elements by			
		Literature review	Researchers	Stakeholder participation[a]	Consultation of Legislation
Newton et al.	2003		x		
Bidone and Lacerda	2004	x	x		
Odermatt	2004	x			
Scheren et al.	2004	x			
Gisladottir and Stocking	2005	x			
Ledoux et al.	2005	x			
Lundberg	2005	x			
Pirrone et al.	2005		x		
Borja et al.	2006		x	x	
Karageorgis et al.	2006	x			
Smaling and Dixon	2006	x			
Agyemang et al.	2007	x		x	x
Holman et al.	2008	x		x	x
Bianet Jago-on et al.	2008	x		x	x
Henriques et al.	2008	x			
Mangi et al.	2008	x		x	x
Chung and Le	2009	x		x	x
Haberl et al.	2009	x			
Kuldna et al.	2009	x		x	
Nilsson et al.	2009	x	x		
Roura-Pascual et al.	2009	x		x	
Research concept		inter- or multidisciplinary	transdisciplinary		

[a] Through expert consultation or elaborated with participatory methods integrating stakeholders.

Table 3
The element *Response* analyzed according to type of response, element definition and targeted actors.

Criterion author	Year	Response constitutes of	Element defined by	End user addressed
Newton et al.	2003	regulatory policies	researchers	government (not specified), science
Bidone and Lacerda	2004	implementation of public management structures, technical provisions	researchers	government (not specified[a])
Odermatt	2004	public information, regulatory policies, subsidies, technical provisions	researchers	science
Scheren et al.	2004	regulatory policies	researchers	government (not specified)
Gisladottir and Stocking	2005	implementation of effective monitoring, public management, regulatory policies, technical provisions,	researchers	government (not specified)
Ledoux et al.	2005	regulatory policies, subsidies, technical provisions	researchers, public and private stakeholders	government (specified[b])
Lundberg	2005	further research, implementation of effective monitoring, public management, public information	researchers	government (not specified), science, general public
Pirrone et al.	2005	implementation of effective monitoring	researchers	government (specified), science
Borja et al.	2006	–	researchers	government (specified), science
Karageorgis et al.	2006	implementation of public management structures	researchers, public and private stakeholders	government (not specified), science
Smaling and Dixon	2006	regulatory policies, individual management options	researchers	government (specified), private stakeholders
Agyemang et al.	2007	regulatory policies, subsidies	researchers, public and private stakeholders	government (not specified)
Bianet Jago-on et al.	2008	technical provisions, regulatory policies, public information, further research	researchers	government (specified), science, general public
Henriques et al.	2008	monitoring, technical provisions	researchers	government (specified)
Holman et al.	2008	regulatory policies, subsidies, technical provisions	researchers, public and private stakeholders	government (specified), science
Mangi et al.	2008	further research, monitoring public information, regulatory policies, public management	researchers, public and private stakeholders	government (not specified), science, general public
Chung and Le	2009	–	researchers, public and private stakeholders	science
Haberl et al.	2009	–	researchers	science
Kuldna et al.	2009	further research, private management, regulatory policies, subsidies	researchers	government (specified), science, private stakeholders
Nilsson et al.	2009		researchers	science
Roura-Pascual et al.	2009	public management structures, regulatory policies	researchers, public and private stakeholders	government (specified), science

[a] Responses which are not explicitly related or directed to policies or certain political actors.
[b] Responses which are explicitly related to policies and or address certain political actors.

DPSIR elements, conceptual models would become more policy relevant. As per definition by Tress et al. (2004), these studies applied a transdisciplinary research concept. Continually from the initiation of these studies, they integrated experts from other fields, laymen, and legislators into the research framework. In those studies, the intention of applying a transdisciplinary approach to the conceptualization of DPSIR was to improve the "real world relevance" of the study. It was considered that this approach was more relevant for actual decision making than those that used inter- and multidisciplinary research concepts.

Criterion (b) "alternative Responses"

Nine out of the 21 used DPSIR applications via scenario development and modeling exercises, or as the starting point for participatory approaches (Table 1). As these studies produced *Response* options rather than single solutions, it was considered that they offered a set of policy options to the decision maker. Few authors (Agyemang et al., 2007; Roura-Pascual et al., 2009) took local *Response* options as *Drivers* to describe an iterative DPSIR cycle. In cases where this was done, especially at the local level, it revealed to policy makers and stakeholders the effects, influences and responsibilities of local processes or activities.

Few studies clearly stated to whom they were directed (Table 3). Policy makers and stakeholders (experts, laymen) may have participated in the research, but decisions based on their results will very likely be considered by different end-users, who do not necessarily correspond to the participating stakeholders.

Because we analyzed studies that were published in peer-reviewed journals, it was not possible to state whether the project outcomes were actually used to support decision making.

Discussion and conclusion

The aim of this study was to ascertain whether the application of the DPSIR framework in research can support decision making. We found that most of the analyzed studies were addressed to political and administrative systems, but only a few studies integrated decision makers into the participative process. Holman et al. (2005, 2008) developed an integrated regional assessment tool. The users of the tool, in this case decision makers, were asked to integrate their requirements and knowledge into the development process, especially during the development of the tool interface. Additionally, based on our experience in the SENSOR project, we found that the participation of the end users of a model or tool is of major importance to achieve its acceptance and to guarantee demand and usefulness with regard to the project product. This finding is in line with the conclusion drawn by De Smedt (2010) who, from a policy making perspective, analyzed the relevancy and legitimacy of research based studies and tools for decision making.

We reached the conclusion that the integration of stakeholders from a variety of fields into the definition of DPSIR elements avoided reliance on single, unidirectional causalities, which was particularly criticized by Niemeijer and De Groot (2008). Through the participative integration of politicians, environmental managers, experts

from other disciplines, journalists, and the general public, "real world" knowledge was integrated into conceptual models, and multiple cause–effect relationships were adopted in many studies.

The example presented in the study by Agyemang et al. (2007) and our own experience showed that experts at a local or regional level may provide highly relevant input for decision options (scenarios), assuming that they are presented in a comprehensive and meaningful way. Similarly to Agyemang et al. (2007), we concluded that the DPSIR framework is an effective approach for structuring data to provide information and allow consultation for the formulation of policy.

We identified the importance of the integration of stakeholders from different levels and end-users of research results into research activities throughout a project's duration. A realistic assessment of concerns, interests and positions may be achieved by asking local stakeholders, as well as outsiders and newcomers, for the integration of their knowledge into cause–effect relationships. The exclusion of local-scale analyses was mentioned as a major drawback of the application of this framework by Carr et al. (2007). A similar criticism presented by Svarstad et al. (2008) may be attenuated by including "various narratives" into the DPSIR cause–effect chain.

Finally, we confirm the considerable potential of DPSIR and the usefulness of its application in research studies by providing policy makers with meaningful explanations of cause and effect relationships. Its application provides a basis for policy relevant research if some further criteria are taken into account. Decision making should be based on solid facts and evidence, which are often rigid, unidirectional, difficult to understand and difficult to communicate. We conclude that the DPSIR framework offers the chance to link scientific findings with "real world" issues and, therefore, may serve as a means of bridging the gap between research and decision making. We found that the application of DPSIR may allow for policy relevant research because it supports the explanation and communication of research results in an accessible and meaningful way to decision makers. It further leads to the presentation of stakeholder values and alternative decision options, rather than to rigid and predetermined solutions.

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References

Adger, W.N., Benjaminsen, T.A., Brown, K., Svarstad, H., 2001. Advancing a political ecology of global environmental discourses. Dev Change 32 (4), 681–715.

Agyemang, I., McDonald, A., Carver, S., 2007. Application of the DPSIR framework to environmental degradation assessment in northern Ghana. Nat. Resour. Forum 31, 212–225.

Bianet Jago-on, K.A., Kaneko, S., Fujikura, R., Fujiwara, A., Imai, T., Matsumoto, T., Zhang, J., Tanikawa, H., Tanaka, K., Lee, B., Taniguchi, M., 2008. Urbanisation and surface environmental issues: an attempt at DPSIR model application in Asian cities. Sci. Total Environ., 16, doi:10.1016/j.scitotenv.2008.08.004.

Bidone, E.D., Lacerda, L.D., 2004. The use of DPSIR framework to evaluate sustainability in coastal areas.Case study: Guanabara Bay basin, Rio de Janeiro, Brazil. Reg. Environ. Change 4, 16.

Borja, A., Galparsoro, I., Solaun, O., Muxika, I., Tello, E.M., Uriarte, A., Valencia, V., 2006. The European Water Framework Directive and the DPSIR, a methodological approach to assess the risk of failing to achieve good ecological status. Estuar. Coast. Shelf Sci. 66, 84–96.

Bowen, R.E., Riley, C., 2003. Socio-economic indicators and integrated coastal management. Ocean Coast Manage. 46, 299–312.

Bullock, H., Mountford, J., Stanley, R., 2001. Better Policy making. Centre for Management and Policy Studies, pp. 1–43.

Carr, E.R., Wingard, P.M., Yorty, S.C., Thompson, M.C., Jensen, N.K., Roberson, J., 2007. Applying DPSIR to sustainable development. Int. J. Sust. Dev. World 14, 543–555.

Cave, R., Ledoux, L., Turner, R.K., Jickells, T., Andrews, J.E., Davies, H., 2003. The Humber catchment and its coastal area: from UK to European perspectives. Sci. Total Environ. 314–316, 31–52.

Chung, E.S., Lee, K.S., 2009. Prioritisation of water management for sustainability using hydrologic simulation model and multicriteria policy making techniques. J. Environ. Manage. 90, 1502–1511.

De Smedt, P., 2010. The use of impact assessment tools to support sustainable policy objectives in Europe. Ecol. Soc. 14 (4), 30, URL: http://www.ecologyandsociety.org/vol15/iss4/art30/ [online].

Commission of the European Communities (CEC). 2005. *Impact assessment guidelines*. European Commission, Brussels, Belgium. SEC 791, 48, URL: http://www.mfcr.cz/cps/rde/xbcr/mfcr/SEC_2005_791_Impact_Assessment_Guidelines_2006update.pdf [online].

Elliot, M., 2002. The role of the DPSIR approach and conceptual models in marine environmental management: an example for offshore wind power. Mar. Pollut. Bull. 44, iii–vii.

Gabrielson, P., Bosch, P., 2003. Environmental indicators: typology and use in reporting. In: Internal Working Paper ,. European Environmental Agency, pp. 1–20.

Gisladottir, R., Stocking, M., 2005. Land degradation control and its global environmental benefits. Land Degrad. Dev. 16, 99–112.

Giupponi, C., Fassio, A., Feás Vàzquez, F., Mysiak, J., 2006. Sustainable water management and policy making. In: Giupponi, C., Jakeman, A.J., Karssenberg, D., Hare, M.P. (Eds.), Sustainable Management of Water Resources – An Integrated Approach. , pp. 71–97.

Gregory, R., McDaniels, T., Fields, D., 2001. Decision aiding, not dispute resolution: creating insights through structured environmental decisions. J. Policy Anal. Manage. 20, 415–432.

Haberl, H., Gaube, V., Díaz-Delgado, R., Krauze, K., Neuner, A., Peterseil, J., Plutzar, C., Singh, S.J., Vadineanu, A., 2009. Towards an integrated model of socioeconomic biodiversity drivers, pressures and impacts. A feasibility study based on three European long-term socio-ecological research platforms. Ecol. Econ. 68, 1797–1812.

Helming, K., Diehl, K., Bach, H., Dilly, O., König, B., Kuhlman, T., Pérez-Soba, M., Sieber, S., Tabbush, P., Tscherning, K., Wascher, D., Wiggering, H., 2011a. Ex ante impact assessment of policies affecting land use, part A: analytical framework. Ecol. Soc. 16 (1), 27, URL: http://www.ecologyandsociety.org/vol16/iss1/art27/ [online].

Helming, K., Diehl, K., Kuhlman, T., Jansson, T., Verburg, P.H., Bakker, M., Perez-Soba, M., Jones, L., Verkerk, P.J., Tabbush, P., Morris, J.B., Drillet, S., Farrington, J., Le Mouël, P., Zagame, P., Stuczynski, T., Siebielec, G., Sieber, S., Wiggering, H., 2011b. Ex ante impact assessment of policies affecting land use, part B: application of the analytical framework. Ecol. Soc. 16 (1), 29, URL: http://www.ecologyandsociety.org/vol16/iss1/art29/ [online].

Henriques, C., Pais, M.P., Costa, M.J., Cabral, H., 2008. Development of a fish-based multimetric index to assess the ecological quality of marine habitats: the Marine Fish Community Index. Mar. Pollut. Bull. 56, 1913–1934.

Holman, I.P., Rounsevell, M.D.A., Cojacaru, G., Shackley, S., McLachlan, C., Audsley, E., Berry, P.M., Fontaine, C., Harrison, P.A., Henriques, C., Mokrech, M., Nicholls, R.J., Pearn, K.R., Richards, J.A., 2008. The concepts and development of a participatory regional integrated assessment tool. Climatic Change 90, 5–30.

Holman, I.P., Rounsevell, M.D.A., Shackley, S., Harrison, P.A., Nicholls, R.J., Berry, P.M., Audsley, E., 2005. A regional, multi-sectoral and integrated assessment of the impacts of climate and socio-economic change in the UK. Climatic Change 71, 9–41.

Karageorgis, A.P., Skourtos, M.S., Kapsimalis, V., Kontogianni, A.D., Skoulikidis, N.Th., Pagou, K., Nikolaidis, N.P., Drakopoulou, P., Zanou, B., Karamanos, H., Levkov, Z., Anagnostou, Ch., 2005. An integrated approach to watershed management within the DPSIR framework: Axios River catchment and Thermaikos Gulf. Reg. Environ. Change J. 5, 138–160.

Kristensen, P., 2003. EEA core set of indicators. Revised version April 2003. Adopted version for ECCAA countries May 2003. Technical Report, pp. 1–79, http://www.unece.org/env/europe/monitoring/StPetersburg/EEA%20Core%20Set%20of%20Indicators%20rev2EECCA.pdf.

Kuldna, P., Peterson, K., Poltimäe, H., Luig, J., 2009. An application of DPSIR framework to identify issues of pollinator loss. Ecol. Econ., 11, doi:10.1016/j.ecolecon.2009.01.005.

Ledoux, L., Beaumont, N., Cave, R., Turner, R.K., 2005. Scenarios for integrated river catchment and coastal zone management. Reg. Environ. Change J. 5, 82–96.

Lorenzoni, I., Jordan, A., Hulme, M., Turner, R.K., O'Riordan, T., 2000. A co-evolutionary approach to climate change impact assessment: part I. Integrating socio-economic and climate change scenarios. Global Environ. Change 10, 57–68.

Lundberg, C., 2005. Conceptualizing the Baltic Sea ecosystem: an interdisciplinary tool for environmental desicion making. Ambio 34, 433–439.

Mangi, S.C., Roberts, C.M., Rodwell, L.D., 2007. Reef fisheries management in Kenya: Preliminary approach using the driver-pressure-state-impact-response (DPSIR) scheme of indicators. Ocean Coast. Manage. 50, 463–480.

Millennium Ecosystem Assessment (MA), 2003. Ecosystem and Human Well-Being: A Framework for Assessment. Island Press, Washington, D.C., USA.

Morris, J.B., Tassone, de Groot, R., Camilleri, M., Moncada, S., 2011. A Framework for Participatory Impact Assessment (FoPIA): involving stakeholders in European policy-making, a case study of land use change in Malta. Ecol. Soc. 16 (1), 12, URL: http://www.ecologyandsociety.org/vol16/iss1/art12/ [online].

Newton, A., Icely, J.D., Falcao, M., Nobre, A., Nunes, J.P., Ferreira, J.G., Vale, C., 2003. Evaluation of eutrophication in the Ria Formosa coastal lagoon, Portugal. Cont. Shelf Res. 23, 1945–1961.

Niemeijer, D., De Groot, R.S., 2008. Framing environmental indicators: moving from causal chains to causal networks. Environ. Dev. Sustain. 10, 89–106.
Nilsson, M., Wiklund, H., Finnveden, G., Jonsson, D., Lundberg, K., Tyskeng, S., Wallgren, O., 2009. Analytical framework and tool kit dor SEA follow-up. Environ. Impact Assess Rev. 29, 186–199.
Odermatt, S., 2004. Evaluation of mountain case studies by means of sustainability variables. Mt. Res. Dev. 24, 336–341.
OECD, 1993. OECD core set of indicators for environmental performance reviews. OECD Environmental Directorate Monographs No. 83. Organisation of Economic Co-operation and Development, 39 pp.
OECD, 2003. Environmental Indicators – Development, Measurement and Use. Report. Organisation of Economic Co-operation and Development, 37 pp.
Perez-Soba, M., Petit, S., Jones, L., Bertrand, N., Briquel, V., Omodei-Zorini, L., Contini, C., Helming, K., Farrington, J.H., Tinacci Mossello, M., Wascher, D., Kienast, F., De Groot, R., 2008. Land use functions – a multifunctional approach to assess the impact of land use changes on land use sustainability. In: Helming, K., Perez-Soba, M., Tabbush, P. (Eds.), Sustainability Impact Assessment of Land Use Changes. , pp. 375–404.
Pintér, L., Hardi, P., Bartelmus, P., 2005. Sustainable Development Indicators Proposal for a Way Forward – Prepared for the United Nations Division for Sustainable Development UN-DSD. 41 pp., http://www. iisd. org/pdf/2005/measure_indicators_sd_way_forward. pdf.
Pirrone, N., Trombino, G., Cinirella, S., Algieri, A., Bendoricchio, G., Palmeri, L., 2005. The Driver-Pressure-State-Impact-Response (DPSIR) approach for integrated catchment-coastal zone management: preliminary application to the Po catchment-Adriatic Sea coastal zone system. Reg. Environ. Change J. 5, 111–137.
Roura-Pascual, N., Richardson, D.M., Krug, R.M., Brown, A., Chapman, R.A., Forsyth, G.G., Le Maitre, D.C., Robertson, M.P., Stafford, L., Van Wilgen, B.W., Wannenburgh, A., Wessels, N., 2009. Ecology and management of alien plant invasions in South African fynbos: accommodating key complexities in objective decision making. Biol. Conserv. 142, 1595–1604.
Scheren, P.A.G.M., Kroeze, C., Janssen, F.J.J.G., Hordijk, J., Ptasinski, K.J., 2004. Integrated water pollution assessment of the Ebrié Lagoon, Ivory Coast, West Africa. J. Marin Syst. 44, 1–17.
Schößer, B., Helming, K., Wiggering, H., 2010. Assessing land use change impacts – a comparison of the SENSOR land use function approach with other frameworks. J. Land Use Sci. 5, 159–178.
SENSOR, 2009.Sustainability impact assessment tools for environmental, social and economic effects on multifunctional land use in European regions, assessed October 2009, http://www.sensor-ip.eu/.
Smaling, E.M.A., Dixon, J., 2006. Adding a soil fertility dimension to the global farming systems approach, with cases from Africa. Agric. Ecosyst. Environ. 116, 15–26.
Smeets, E., Weterings, R., 1999. Environmental indicators: typology and overview. Technical Report No. 25, pp. 1–20.
Svarstad, H., Kjerulf Petersen, L., Rothman, D., Sieple, H., Wätzold, F., 2008. Discursive biases of the environmental research framework DPSIR. Land Use Policy 25, 116–125.
Svarstad, H., 2002. Analysing conservation-environment discourses: the story of a biopiracy narrative. Forum Dev. Stud. 29 (1).
Svarstad, H., 2004. A global political ecology of bioprospecting. In: Paulson, S., Gezon, L. (Eds.), Political Ecology Across Spaces, Scales and Social Groups. Rutgers University Press.
Thiel, A., 2009. The use of ex-ante modelling tools in European Impact Assessment: what role does land use play? Land Use Policy 26, 1138–1148.
Tress, G., Tress, B., Fry, G., 2004. Clarifying integrative research concepts in landscape ecology. Landsc. Ecol. 20, 479–493.
Tscherning, K., König, H., Schösser, B., Helming, K., Sieber, S., 2008. Ex-ante impact assessments (IA) in the European Commission – an overview. In: Helming, K., Perez-Soba, M., Tabbush, P. (Eds.), Sustainability Impact Assessment of Land Use Changes. , pp. 18–33.
Turner, R.K., Subak, S., Adger, W.N., 1996. Pressures, trends, and impacts in coastal zones: interactions between socioeconomic and natural systems 7. Environ. Manage. 20, 159–173.
UN, 1996. United Nations. Indicators of sustainable development. Framework and Methodologies. Report. 428 pp.