Integrated sustainability assessment of water systems: lessons from the Ebro River Basin

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Abstract: This paper describes the co-development and implementation of visioning and experimenting exercises, agent-based modelling, and gaming tools in Integrated Sustainability Assessments (ISAs) involving stakeholders. These new tools are aimed at supporting reflexive learning and at building alternative policy-relevant knowledge and evaluative paradigms for managing sustainability. The specific case study relates to water management within the Ebro River Basin. Conclusions concern the use of these tools to represent complexity, to learn how conflict and collaboration between agents can be addressed, and to explore the roles played by power regimes, institutional rules, and culture in constraining or enhancing transition in the water domain.

Keywords: Integrated Sustainability Assessment; ISA; water management; Ebro river basin; sustainability transitions; agent-based modelling; gaming tools; social learning; sustainability learning; reframing.
1 Introduction

Most current tools and methods for the assessment and management of environmental and sustainability problems tend to focus on a single area of reality, address only one type of constraint and are based on assumptions about the use of knowledge aimed at reinforcing existing regimes rather than transforming or replacing them. This situation highlights the need for new approaches working at the science–policy–society interface.
capable of dealing with complex problems of sustainability by taking a broader and more systemic perspective and by focusing more explicitly on agents and agency.

The MATISSE project aims at developing new reflective methods and tools capable of supporting the co-production of socially and ecologically robust narratives and of stimulating social learning and integrated (multi-level/multi-domain) action on persistent problems. For the case of water, we argue that such narratives can be best developed if they take a systemic agent-based perspective. We argue that as we shift the emphasis from the assessment of “what is the problem” towards “who can contribute to solutions and in what ways”, issues concerning the mutual dependence of actors and their co-responsibility in implementing solutions can best be unveiled, as well as costs and benefits deriving from the use of scarce resources such as water.

This paper provides a description of the development and application of the ISA framework (Weaver and Rotmans, 2006; Weaver and Jordan, 2008; Tàbara, 2006) to a concrete system of reference: the Ebro river basin in the Iberian Peninsula. It covers the first iteration of the ISA cycle that was carried out between April 2006 and May 2007. A total of 22 stakeholders participated in three meetings, contributing their insights and reflections in a process of co-developing and co-applying new ISA tools and methods in association with a scientific team comprising nine researchers. By describing how each of the consecutive phases of scoping, envisioning, experimenting, and learning has been implemented the paper illustrates how the ISA template, which integrates both process-related and analytical dimensions, was used in the Ebro River Basin case study.

2 Stage I: Scoping

A first task in the scoping stage was to describe the system of reference, based on both expert/non-expert and quantitative/qualitative sources of knowledge. An extensive search on the socio-economic, institutional and environmental conditions of the Ebro river basin was carried out at the very beginning of the process. This research was facilitated by the large amount of data already available from the river basin authority (CHE, 2005; Tàbara et al., 2007a). This scoping period also integrated knowledge from interaction with a diversity of stakeholders from science and policy domains as well as environmental NGOs. This stage also included insights gained from two meetings: the first one was with nine stakeholders in November 2005 and the second one, with the same number, in March 2006. Many other in-depth interviews and regular contacts with stakeholders were carried out during this time (for further details, see Tàbara et al., 2007a).

2.1 Description of the system of reference

The Ebro river basin is the largest river basin in Spain and is located in the North-Eastern part of the Iberian Peninsula (Figure 1). Its waters flow through nine Autonomous Communities in Spain, each one with its own parliament and competences on water issues. However, a general river basin authority, the Confederación Hidrográfica del Ebro, exists to coordinate actions at the whole river basin scale. Its main urban populations are concentrated around Zaragoza, capital of Aragon, Victoria in the Basque Country and Pamplona, in Navarre. The largest economic activity and one that employs most people in the Ebro River Basin is the services sector, followed by industry and then
agriculture and primary activities. However, as shown in Tables 1 and 2, while energy production and agriculture have relatively very low percentage contributions to economic growth and employment (3.49% and 5.7% of the total income and 6.54% and 3.49% of the employment, respectively) these two sectors constitute the largest water users. Between 5300 Hm$^3$/year and 7000 Hm$^3$/year of water are actually consumed and do not return to the water system, roughly one-third of the average yearly total water contribution of the river basin.

**Figure 1** Ebro River Basin location and aerial view of the location of its Delta

![Ebro River Basin location and aerial view of the location of its Delta](image)

**Table 1** Economic output and employment distribution in the Ebro River Basin in 2002

<table>
<thead>
<tr>
<th>Ebro river basin type of economic activities</th>
<th>1000 euros</th>
<th>Total (%)</th>
<th>Employment</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture, livestock, and fishery</td>
<td>2,305,341</td>
<td>5.72</td>
<td>81,000</td>
<td>6.54</td>
</tr>
<tr>
<td>Industry including energy and construction</td>
<td>15,788,307</td>
<td>39.16</td>
<td>442,000</td>
<td>35.61</td>
</tr>
<tr>
<td>Energy</td>
<td>1,407,335</td>
<td>3.49</td>
<td>8,000</td>
<td>0.61</td>
</tr>
<tr>
<td>Industry</td>
<td>11,277,745</td>
<td>27.97</td>
<td>317,000</td>
<td>25.52</td>
</tr>
<tr>
<td>Construction</td>
<td>3,103,227</td>
<td>7.70</td>
<td>118,000</td>
<td>9.48</td>
</tr>
<tr>
<td>Services</td>
<td>23,768,629</td>
<td>58.96</td>
<td>718,000</td>
<td>57.86</td>
</tr>
<tr>
<td>Trade services</td>
<td>18,166,893</td>
<td>45.06</td>
<td>480,000</td>
<td>38.65</td>
</tr>
<tr>
<td>Non-trade services</td>
<td>5,601,736</td>
<td>13.89</td>
<td>238,000</td>
<td>19.20</td>
</tr>
<tr>
<td>Total</td>
<td>40,315,633</td>
<td>100.00</td>
<td>1,242,000</td>
<td>100.00</td>
</tr>
</tbody>
</table>


**Table 2** Water use in the Ebro River Basin by economic activities – 2005

<table>
<thead>
<tr>
<th>Water use</th>
<th>hm$^3$/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy production</td>
<td>41,100</td>
</tr>
<tr>
<td>Agriculture and livestock</td>
<td>6,310</td>
</tr>
<tr>
<td>Aquaculture</td>
<td>1,000</td>
</tr>
<tr>
<td>Domestic use</td>
<td>506</td>
</tr>
<tr>
<td>Leisure uses</td>
<td>300</td>
</tr>
<tr>
<td>Industry (non connected to main system)</td>
<td>250</td>
</tr>
<tr>
<td>Total</td>
<td>49,466</td>
</tr>
</tbody>
</table>

*Source*: CHE (2005, p.95)
The Ebro River Basin is a primary zone for intensive and irrigated agriculture. For instance, 60% of fresh fruit in Spain are produced here, and the Ebro River basin exports large quantities of fruit to the rest of the world. Non-irrigated crops consist mainly of winter cereals, while forage, maize and winter cereals together dominate irrigated agriculture. By the end of the 1980s livestock production, particularly in the expanding poultry industry, began to be an important sector in the area. Animal husbandry and meat production has been on the rise also in the last decade. One-third of meat production of Spain comes from the valleys of the Ebro river basin (CHE, 2005). With regard to pollution derived from agriculture, the main problems concern overuse and run-off of the major macro-nutrients (characteristically Nitrogen, Phosphorous and Potassium), which are applied both to non-irrigated and irrigated crops. Other negative impacts of agriculture on soils and water arise through mounting manure residues from livestock and the use of sewage sludge as a soil treatment. Irrigated agriculture also contributes to an increase in the salt content of soils, which constitutes one of the most acute environmental problems of the basin, which has a saline concentration that is three times the world average. Approximately 310,000 ha of the basin suffer from salt contamination (MMA, 2003). Pollution from chemical and radiochemical industry is also important in the river basin, as in the case of the town of Flix, where large quantities of non-treated wastes have been accumulating for decades in the sediments of a nearby reservoir. However, a plan to deal with this highly toxic waste is now underway.

Half of the total land in the Ebro River Basin consists of potential agricultural land. The irrigated land surface covers more than 3 million hectares with a water use of some 240 Hm³/year. Around two-thirds of this potential area is ploughed for agriculture. However, ploughing increases the rate of erosion. About half of the total land of the Ebro River Basin suffers from moderate or higher levels of erosion (see Table 3). Highest levels of erosion are seen especially in the coastal zones. There is heavy erosion, also, in the mountainous areas in the south-west part of the basin, where animals graze, although there erosion is a natural process as well.

Table 3  Erosion in the Ebro river basin

<table>
<thead>
<tr>
<th>Level of erosion</th>
<th>Loss of soil (ton/ha/year)</th>
<th>Affected land and percentage (Ha) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme erosion</td>
<td>100–200</td>
<td>125,000</td>
</tr>
<tr>
<td>Very high erosion</td>
<td>50–100</td>
<td>250,000</td>
</tr>
<tr>
<td>High erosion</td>
<td>25–50</td>
<td>650,000</td>
</tr>
<tr>
<td>Moderate erosion</td>
<td>12–25</td>
<td>2,470,000</td>
</tr>
<tr>
<td>Low erosion</td>
<td>5–12</td>
<td>3,142,000</td>
</tr>
<tr>
<td>Very low erosion</td>
<td>0–5</td>
<td>1,860,000</td>
</tr>
</tbody>
</table>

Source: CHE (2005)

According to the stakeholders consulted in the process, an important issue regarding the unsustainability of the river Ebro basin is the large number of dams, 38 in total in this area. They have an immediate impact on the river flow but their impact extends to other landscape and biophysical conditions of the whole river basin. Physical alterations caused by dams are related to hydrological regime, temperature and sediments. Chemical alterations are due to biological processes that takes place in the water upstream and...
downstream of dams. Furthermore blocking of sediments by the dams results in the erosion of the delta and impacts on the marine food chains that lead to a decrease of food for coastal fish. In addition, it is estimated that climate change will also impinge on the water availability of the Ebro river basin, with an expected reduction of 16% in precipitation as rainfall by year 2060 (Ayala-Carcedo, 2001). Climate change may also expand the tourism season in littoral areas, although it is also quite likely to affect negatively other tourist activities related to winter and snow sports.

Given this situation, new practices are being developed to cope with mounting water scarcity and constraints in different sectors. For instance, in agriculture new irrigation techniques are increasingly playing a greater role in improving water use efficiency. However, at present, irrigation by gravity is still the most widespread technique used, although it is largely water inefficient given the high temperature of the area that results in high evaporation rates.

2.2 Stakeholder interaction: Integrated Sustainability Assessment focus groups

Our interaction with stakeholders during the first iteration of the ISA process followed and adapted a methodology known as Integrated Assessment Focus Groups (IA-FGs, Kasemir et al., 2003; Dürrenberger et al., 1999; Hare et al., 2006). This methodology was used to help frame the nature of unsustainability in the use and management of water resources. While our first efforts concentrated on the river basin scale, our purpose was also to develop tools and methods that could be used by stakeholders to assess the sustainability of the use of stocks and flows of water at different scales. This participatory technique also proved useful to start developing shared visions on sustainable futures, and to analyse the feasibility of ISA in this particular context (Hare et al., 2006). This interaction was based on a previous institutional analysis of the main stakeholders operating within the basin, including from the Spanish and Autonomous governments as well as agents operating at river basin and sub-basin levels (Tàbara et al., 2007a).

During the first meeting, stakeholders identified several important problems that in their view affected the Ebro river basin. Their insights complemented the data obtained through secondary sources as well as from interviews before the meeting. Participants felt that the river basin water resources are dwindling owing to the rising pressures from multiple and growing uses. Besides the water uses listed in Table 2, they mentioned that now there is an ‘additional user’ or demand for water: that of the river itself. Increasingly, the river is perceived as a new kind of (non-human) ‘user’, an ecological system that has its own water requirements for maintaining its intrinsic properties and dynamics.

In this first interaction, some of the river basin authority agents remarked that in the Ebro basin there is a lack of legitimacy of the existing water management and planning institutions. This affects the river basin authority and its capacity to operate. Such a lack of legitimacy relates to the history of this agency, regarding the way that decisions were taken in the past, mostly during the Spanish dictatorship, and how such decisions involved only selected interests and promoted the building of large water infrastructures that were often unpopular. The agents felt that it is very difficult to change such perceptions, despite the new approach now heralded by the European Water Framework Directive. With regard to public participation, some officers of the river basin authority felt that, while positive, public participation processes may allow some stakeholders, like political minority parties or ‘radical environmentalists’, to hinder their capacity to
act in the area. They felt that public participation processes may also slow down decision-making, management, and planning procedures to a considerable extent.

In this meeting, stakeholders also talked about the existence of persistent conflicts between different agents and stakeholders within the river basin. They remarked that while the overall goals of the majority of relevant stakeholders are essentially similar with regard to the use of water, there are important differences concerning both the measures that stakeholders consider appropriate and organisational aspects of management and decision-making, such as who has decision authority and the role of public involvement. In this regard, the people from the river basin authority felt that the Ebro River Basin is a particularly conflict-laden basin in Spain. They argued that stakeholders are more powerful than in other Spanish basins and given the large number of regional governments involved in the Ebro river basin this brings about more conflicts. As remarked by one member of the river basin authority, “We have a very difficult bullfight going on here; while in other basins they have only young cows, here we have bulls that look like beasts”… In other words, a key issue of concern appeared to be how to create processes of collaboration to achieve common goals given the existing historical conflicts between agents of the river basin.

In handling this situation experience from analogous complex and potentially confrontational situations suggests focusing on the ends rather than the means in the first instance, and striving toward a long-term future vision that enables stakeholders to put short-term considerations temporarily to one side. This experience is embedded in the ISA approach. We made use of this experience during the second meeting, which was based not only on oral deliberation, but included also some participatory activities such as dynamic systems representation (Pahl-Wostl and Hare, 2004) and scenario making using the collage technique (Kasemir et al., 2000). We also included the first attempt to conceptualise our suite of ISA models and tools with the help of the stakeholders. This second meeting was held at the premises of the New Water Foundation, an organisation that had been decisive in articulating claims and changes in management practices within the Spanish policy context (Tàbara and Ilhan, 2007). It included representation from not only the ‘regime’ but also more ‘non-regime’ stakeholders. A main purpose of this meeting was to start testing different methods and tools specifically designed to support ISA. In particular, we wanted to integrate different types of knowledge and perspectives, and to start sketching the first ideas for an integrated modelling framework that could support the representation of and reflection on water unsustainability problems in the area.

A first participatory exercise consisted of a system representation of the problems in the Ebro Basin, the results of which are shown in Table 4. Simply, stakeholders were asked to discuss first freely about causes and effects of and responses to water-related problems in the area and then complete the table, whenever possible, with their ideas. At the beginning, the main focus of attention related to single problems directly linked with the environmental dimension (e.g., pollution, subsidence, deforestation, …), which were understood to be the result of the past and present practices in the exploitation and management of the natural resources of the river basin, under what has been called the ‘structuralism paradigm’. In particular, the structuralism paradigm is associated to the view and the dominant traditional management practices of increasing water supply to users, building large infrastructures, and conceptualising water only as a factor in economic production (largely disregarding its ecological, community, or cultural significance). But progressively, a more systemic and relational worldview emerged
during the discussions. Several participants perceived and explained the changes
in the Ebro river basin and in particular in the delta in a more dynamic and
coevolutionary way. They understood that river basin transformation was due to
a close, dynamic relationship between natural resources and human exploitation:
“Changes in rice crop production affect biodiversity”; “water irrigation management
affects crops …”. So increasingly it was felt among the participants that a more complex
and richer perspective was needed to comprehend and appraise the system. As had been
expected, the economic dimension was perceived to be a main driving force of change.
The increasing pressures from tourism and the crisis of the agricultural sector were
underlined as the main ones.

Table 4 Cause–effect–response matrix developed by the participants during the second
workshop

<table>
<thead>
<tr>
<th>Economic Causes</th>
<th>Environmental Causes</th>
<th>Institutional Causes</th>
<th>Cultural Causes</th>
<th>Technological Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural market</td>
<td>Intensive</td>
<td>Absence of</td>
<td>Traditional</td>
<td>Hydroelectric</td>
</tr>
<tr>
<td>sustainability</td>
<td>agriculture</td>
<td>integrated</td>
<td>power</td>
<td>power</td>
</tr>
<tr>
<td>River Basin</td>
<td>Deforestation</td>
<td>management</td>
<td>structures</td>
<td>Uncontrolled</td>
</tr>
<tr>
<td>Regulation</td>
<td></td>
<td></td>
<td></td>
<td>groundwater</td>
</tr>
<tr>
<td>Tourism</td>
<td>Wind energy parks</td>
<td>Public participation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Urban laws</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>disconnected with</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>landscape</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of economic</td>
<td>Foreign species</td>
<td>Old water culture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>resources at local level</td>
<td>introduction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ecosystems</td>
<td>No participation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>fragility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Landscape</td>
<td>Humanisation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>process</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Economic Effects</th>
<th>Environmental Effects</th>
<th>Institutional Effects</th>
<th>Cultural Effects</th>
<th>Technological Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice production</td>
<td>Salinisation</td>
<td>Non-coordinated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>decreasing</td>
<td></td>
<td>administrations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New projects, new</td>
<td>Subsidence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>social conflicts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human occupation of</td>
<td>Habitat loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>risky spaces close to</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>the river</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Contamination</td>
<td></td>
<td></td>
<td>Delta regression</td>
</tr>
<tr>
<td></td>
<td>Species loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disadvantages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>to the primary sector</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Delta regression</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4  Cause–effect–response matrix developed by the participants during the second workshop (continued)

<table>
<thead>
<tr>
<th>Economic Responses</th>
<th>Environmental</th>
<th>Institutional</th>
<th>Cultural</th>
<th>Technological</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality labelling for local farm products</td>
<td>Hard protective measures</td>
<td>Associations</td>
<td>Social movements demonstrations and actions</td>
<td></td>
</tr>
<tr>
<td>Water quality</td>
<td>Institutional coordination</td>
<td>Agenda 21</td>
<td>Non-normative management plans</td>
<td></td>
</tr>
<tr>
<td>Water circulation</td>
<td>Environmental indicators</td>
<td>Cooperation plans</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

However, as the activity proceeded, the focus shifted to the institutional context. One of the most relevant results of the workshop was the strong perception that the participants developed about the key role of the institutional dimension when thinking about the sustainability of the Ebro Delta. The participants agreed that the lack of integrated management of the river basin was linked to institutional fragmentation. For example, they mentioned the impacts caused downstream due to construction of dams. Water regulation for irrigation, industrial and urban uses, and flood risk control have provoked regression and subsidence problems in the delta system. These are seen as the result of a sectoral perspective in the management of the river and of the partial framing of the issues. Further, conventional assessment methods, like environmental impact assessment, are only focused on dealing with particular parts of the system, like building dams or extending irrigation to arid areas and therefore they do not take an integrated view of the river basin. Another example that was given was the historical division of the Delta into two administratively separate parts, which often do not collaborate with each other.

Hence, the general perception of the participants was that there are too many overlapping and uncoordinated administrative bodies responsible for different parts of River Basin Management and that either a restructuring of responsibilities or much stronger coordination between bodies is needed, especially when these are from different institutional levels (national, provincial or local). In the coastal areas of the delta, for instance the Public Maritime Domain is in the hands of the Central Spanish Government, whereas the inner coastal zone is under the control of the Catalan autonomous government, while the management of the navigation channels is the responsibility of the Spanish Ministry of Public Works. Likewise, there are two different counties and numerous local municipalities that have competences in the planning of the Delta. Administrative fragmentation and lack of collaboration were seen as a major hindrance to overcoming current trends towards unsustainability.

This first scoping exercise contributed to a detailed representation of drivers of unsustainability within the Ebro basin. It was possible to assess relationships between the origins and the effects of processes of both human and natural systems dynamics in an interrelated and integrated way. Through the cause–effect–matrix exercise, the participants were able to connect the impacts of human actions with economic, cultural, ecological, technological and institutional dimensions. But at the same time, many
Integrated sustainability assessment of water systems

processes could not be classified easily in what was probably a too rigid classification of problem categories, effects and responses. However, this activity helped to uncover some linkages among processes occurring at different scales in the management of water resources in the area. Another output of this exercise was the emergence of a more systemic and relational narrative of the problems of the river basin. The perception of the river basin, and in particular the delta, as a dynamic area in which two-directional interactions between nature and society occur, confirmed the presence of more co-evolutionary worldviews among the stakeholders. This discourse, more closely related to non-regime actors, contrasted with the hegemonic position in the traditional hydraulic paradigm of increasing water supply and defending the ‘human control of nature’. In that sense, this second stakeholder meeting of the scoping phase opened up the debate and broadened the problem framing. Nevertheless, and similar to the findings of the first meeting, one of the key questions that arose from this second exercise regarded what type of institutional setting should best be designed to allow people to cope with unsustainable problems of the Ebro river basin in a more collaborative way.

3 Stage II: Envisioning

During the first meeting with stakeholders, given its exploratory character, we did not ask participants to provide a detailed vision of the sustainable future for the river basin. Instead, according to them, the most important question was about what should be done to create the necessary alliances and gather the right knowledge to meet the ‘vision’ already contained in the European Water Framework Directive (WFD). According to the participants, the management of the Ebro river basin faces a great and unavoidable challenge, because all realistic visions of the future must take into account what the WFD sets out. Agencies need to consider how to develop strategies for open participation processes following the provisions and timetables provided by the WFD. Visions need to accommodate this institutional framework. However, some participants, spontaneously, provided us with their own perspective on a sustainable future. Among those, a long-term Spanish environmentalist and university professor eloquently mentioned with regard to water management issues that:

“There are two main worldviews about nature and how society and nature should interact: the ‘promethean culture’ and the ‘new water culture’. The first, which comes from the Illustration, sees nature as a mistake, as something that needs to be corrected by engineering. The second is based on saving (conservation) and recycling the water resources. However, in order to change that culture, we need above all, re-education, but this may take 10 or 15 years. In this respect, a good strategy to start re-educating the people is by connecting the problems to their immediate experiences. In our case, this can be done by declaring the ‘right to free good drinking water’, that is, to high quality water for which we don’t have to pay. [Suggesting that if that right was enforced, many rights to pollute or extract water resources by companies would not be possible.] Until now, the Spanish experience in water resource management has embraced a ‘hydro-technocratic’ culture, where nature was seen as something to be tamed and corrected. So far, there has been a ‘patrimonial’ vision of management and in deciding who could be involved in the planning of water
resources. In this way, only those users or property owners who had a stake could participate. This needs to change. Perhaps it’s high time to start thinking about making our rivers wild again so that we have to begin to pull down some dams to restore the rivers. Why not?”

This vision, which contained the need for a change of culture, as well as a need for public engagement in the restoration of river basins was indeed broader and more far-reaching than the ideas (or vision) argued by the main regime representatives, namely from the river basin authority, who mostly were interested in knowing what needs to be done to implement and comply with the WFD requirements.

During the second meeting, we held exercises aimed at further refining the different visions and trying to make them more operational. For practical reasons, many of the discussions focused to the river delta, where the meeting took place, although we were interested also in knowing how participants saw the relationships among different dimensions of the problems at different scales. Specifically, we split the group into two, we asked participants to think about two different future scenarios for the Ebro Delta in 30 years time, and then to elucidate strategies or pathways that could help to reach those future states. This activity consisted of a visioning exercise using collages to generate a sustainable scenario of the delta in contrast to a business as usual one. For that exercise, participants used images from colour magazines that they cut out and pasted on land-use maps of the delta, see Figures 2 and 3.

Figure 2 Envisioning exercise using the collage technique in the Ebro river basin
Two pairs of scenarios were generated – two per subgroup – and these were grouped in two categories. After a plenary session, the participants named and described them as follows:

**Technical-expert future.** These visions mainly focussed on explaining the causes of the multiple problems as if it were possible to deal with them one by one, on an individual basis. Problems such as those resulting from energy extraction, coastal erosion, loss of aquaculture or population growth, can be dealt with using technical and expert solutions. Generally, participants believed that these solutions would improve and reinforce the biophysical capacity of the system to cope with environmental problems. In this sense, despite their managerial style, several identified proposals were innovative and had a quite systemic perspective, such as the ‘managed realignment strategy’ of the shoreline and the restoration of the wetlands in order to deal with changes and dynamics of the delta. In Spain, this kind of alternative had not been considered so far as a realistic option for coastal management, on the one side, because of large urban and tourist pressures on the coastline and on the other because the debate on coastal realignment (e.g., as a result of climate change) has not yet trickled down in Spain.

**Socio-institutional future.** These visions were related to the institutional and organisational aspects, so as to enhance the collaboration between agents working at different levels, as opposed to a fragmented world in which individuals and organisations pursue their interests and benefits in an un-coordinated and shortsighted manner. One of the main findings of the workshop held with local stakeholders in the Ebro delta was that there is an urgent need to coordinate and strengthen social networks because
sustainability implies a large degree of empowerment and coordination between different agents at different scales. In particular, an emerging vision of sustainability is that unsustainability is the result of the lack of conscious collaboration between agents working at different levels with the overall goal to reduce their impacts on aquatic systems and on other agents. The participants believed that – with beauty of the landscape and the ecological value of the river basin being the main sustainability resources – sustainable development depends primarily on the better organisation, planning and coordination of the institutional context. This vision contrasted with conventional perspectives that support more traditional assessment processes focused on end-of-pipe and separate effects. These effects have already entered into the socio-ecologic systems and are dealt with in a fragmented way, rather than dealing with the whole network of relationships between the ultimate causes and their systemic effects on the social–ecological systems.

Our expectation of the envisioning exercise was that this would promote the development of a common worldview with regard to a possible sustainable future of the Ebro river basin or reveal the existence of two or more different visions and the underlying reasons for the differences (as the basis for using these differences as a source of creative tension in the exploration of solutions). While it is true that through these participative procedures some emerging perspectives and perceptions increasingly highlighted the need to address institutional issues in order to enhance future sustainability of the river basin, we cannot say that in this first iteration of the ISA cycle we managed to obtain very concrete visions. A lesson learned from this experience is that we may have to emphasise more the role of a ‘desired future’ rather than a possible one, in a way that it could inform policy action in a more explicit way. This could have prevented some of the earlier tensions and would have helped to find a common ground for dialogue if applied properly. However, the two possible future visions that emerged in outline at least, the technical-expert and the socio-institutional, may not be exclusive but complementary, and, in practice, any desired and sustainable future of the river basin will most likely have to integrate them both as part of the assessment and management process.

In short, participants believed that more coordinated collective action is necessary to address problems of unsustainable development and to adapt to the changing future and to the dynamic environment of the Ebro river basin. However, such coordination may depend in the first place on building the necessary trust and social capital. In this sense, it now becomes clearer that methods and tools of ISA that support collective action in a bottom-up participatory fashion and take into account such relational approaches are well suited to reach this goal. This may result in assessment and management practices less based on delegation and more based on personal engagement and agent collaboration. The question then arises in our case about the extent to which it is possible to contribute to this cooperation and the organisation of the large number of formal and informal social networks. And what is the role of tools in representing the potential for such collaboration? Our exercises helped in reflecting on the opportunities and difficulties for transitional changes towards sustainability and in particular about the great challenge of learning ‘how to collaborate’, although we felt that we did not yet have to hand the tools to support such agent collaboration. The implication was that these would have to be built. Yet this conclusion was not without controversy.
4 Stage III: Experimenting

The experimenting stage focused mostly on developing and applying specific tools and in particular an integrated modelling framework, capable of supporting the ISA of water. The framework also includes a role game and other components, such as a visioning module called a ‘visioning trip’. However, and against this backdrop, we were warned about our ambition to develop new tools. According to a member of the river basin authority, the most important thing, rather than developing new tools, was to increase the trust in the Ebro river basin management agencies. In his words: “we do not need new tools, we already have many. What we need is to apply the ones we already have and take the most advantage of their potentialities”. One explanation of this statement could be that new tools can create potential opportunities for change and for redefining problems in a way that may threaten the existing regime. Also, existing tools often respond to ‘desired futures’ that are already in accordance with regime goals whereas developing visions of alternative futures and exploring how to reach these may require that new tools and methods are developed.

Certainly, existing modelling tools for providing insights into managing the Ebro river basin are limited in scope and tend to be regime-oriented rather than transition-oriented. We therefore considered it essential to deploy some efforts in developing specific tools to support the ISA process. The meeting held in March 2007 was the first attempt to use prototypes of two new tools that we developed, a model and a game, with stakeholders in the Ebro river basin. The stakeholders had contributed earlier to the identification of the main concepts and helped to build the first architecture of the model (Tábara et al., 2007b).

First, a multi-scale, social agent-based modelling tool capable of being used in participatory settings, called the World Cellular Model (WCM) framework was developed (Tábara et al., 2007b). While development is still in progress, the WCM focuses on the representation of agents’ behaviours and their systemic relationships with their environment. This framework consists of a linked agent-based and hydrological system representation and includes a user-friendly interface in the form of a water game. The result of such interactions between agents and the hydrological system are then shown in user-friendly charts and interfaces (see Figure 4). Some key characteristics of the WCM approach are:

- **It is agent based.** The WCM takes ‘agents’, rather than ‘the environment’ as its point of departure. The agents are intrinsically linked through their interactions with a common environment and their dependencies on a minimum share of the stocks and flows of water, referred to as ‘kinetic water’. Trade-offs between economic, social and ecological water functions are thus essentially assumed to be trade-offs amongst interdependent agents operating within a common system or resource pool.

- **It takes a systemic perspective.** The interface between the agents and their water environment is described using the different components of the SEIC model (Tábara and Pahl-Wostl, 2007). The water use strategies of each agent in response to environmental pressures depend on the availability of energy (E) (e.g., to transport water), the institutional context and social structure (S), and the information base about the environment (I). In turn, the water and energy use of agents create new pressures on the environment (for instance, increasing CO₂
emissions), eventually leading to new co-evolutionary impacts on the agent network in the form of socio-ecological change (C).

- **It shows agent responsibility for socio-ecological change.** The agents’ environmental impacts such as water use and pollution are represented in terms of the agents’ size and transformation. This shows the sustainability of current practices, and the relative agent contributions to resource use and environmental and social impacts. It thus makes clear the responsibility for environmental (and social) degradation or improvement.

- **It is multi-scale.** In the WCM the agents are hierarchically organised along multiple scale levels (generally geographical) with individual agents forming collective agents, which form higher-order collective agents within a single total earth system. Multi-scale interactions are mediated by different types of water flows, including natural flows (upstream to downstream), pumping (downstream to upstream), inter-basin transfers (between neighbouring cells) and flows of virtual water (between distant cells) contained in the production of water services and in products that have been produced using water, such as crops (Hoekstra and Hung, 2005).

**Figure 4** The world cellular framework

![World Cellular Framework](image-url)
Therefore the WCM framework contains:

- An agent-based model that represents main agents of the system of reference and their behaviours.
- Stakeholder analysis (their personal and institutional aims and interests, necessary to find win-win proposals).
- Choice of actors in the process in the conceptual phase and in implementation.
- A proposal of the process architecture.
- A descriptive module with a series of data sets on river basin characteristics (water uses, needs and trends) and outputs from the running of the model.
- A descriptive module with a series of data sets on external ‘landscape’ trends, such as in technology, environment at large (e.g., climate), available resources (e.g. energy), political developments, demographic developments, etc.
- A system model containing quantitative representation of biophysical dynamics.
- Two modules to enhance the social-ecological robustness of the WCM approach and modelling interface. These modules are:
  - A virtual river trip: in which users of the WCM framework can visualise both current and future states of the river depending on a baseline scenario or on particular development pathways and policy options. In this sense it is a tool both to illustrate how the future of the river may look if particular agent behaviour is extended to the rest of the system and to reflect upon what actions are needed to prevent a particular (undesirable) future state of the river basin from arising.
  - A role-playing game: aimed at gaining insights into the drivers of agents’ behaviours and dynamics and exploring to what extent the agents identified and selected by the model correspond to those that are relevant and influential in the system of interest.

The gaming tool intends to facilitate a structured dialogue amongst stakeholders, obtain a socio-ecologically robust description of agents’ behaviour, and support both modelling and integrated reflection on unsustainability in the use of water in the river basin. It aims to support reflexive learning in the domain of water. It can also be used as an empowering tool to demonstrate differences in the agents’ policy competences and fairness in the distribution of power. The first version of the game was part of the ISA experimenting stage, in which the insights obtained during the scoping and visioning stages could be tested and refined. In particular the goals of the tool are:

- To improve and test in a reflexive way the description of the system of reference and of the ISA sustainability vision. Stakeholders are asked to agree on a common strategy to meet future water demands and scarcities and consider new constraints such as climate change. However, to do so, several pathways are possible and agreement on these is not guaranteed. Agreement depends on the capacity of agents to collaborate with each other and on developing a convincing and powerful narrative that carries legitimacy and is socially robust.
• To build such narratives.
• To help stakeholders to link individual behaviours with system constraints and
dynamics in a multi-scale fashion.
• To specify the motives and constraints of the key agents affecting the water system.
This should inform the agent-based modelling tool and the spatial representation of
their landscape impacts in the World Cellular Model.
• To reflect upon the idea of a management transition in the domain of water taking
into account the multiple interdependence of systemic constraints.
• To show the importance of narrative building and the need for agent collaboration
and policy commitments in sustainability transitions.

When playing the game, stakeholders are stimulated to reflect upon the unsustainability
in the utilisation of water, and on the dynamics of social and cultural change underlying
possible changes in water use behaviour. The game also intends to help the improvement
of the vision obtained during the previous ISA stage by specifying the goals, measures
and system constraints that agents face in developing a transition strategy. The first
running of the game with real stakeholders in the Ebro river basin in March 2007 helped
to determine the potentialities, as well as the remaining weaknesses, of this tool, which
overall shows promise of being able to help stakeholders to simulate and experience a
range of situations and plausible futures.

5 Stage IV: Evaluating and learning

One of the most noticeable symptoms of persistent unsustainability of the Ebro river
basin system –as well as of other Spanish river-basins – was expressed in the conflicts
that arose from the making of and failed attempt to implement the last National Water
Plan (NWP). This Plan, which was withdrawn by the new government after the national
elections in 2004, proposed a large water transfer from the Ebro river basin to other
‘deficit’ river basins, mostly to provide for the water demands of intensive agriculture
and tourism. The proposal was highly criticised for not taking the social and ecological
impacts of the whole Ebro river basin sufficiently into account, and because it framed the
issue as a ‘water scarcity problem’ (i.e., as an economic demand/supply optimisation
question), rather than considering multiple issues of river-basin resource and landscape
management in a more systemic and comprehensive way.

The National Hydrological Plan caused a wide social upheaval and exacerbated
differences between the different regions, manifested in the largest demonstrations on
socio-ecological issues taking place in Spain for over two decades. However, this resulted
in the creation of new collaborative networks of action, even with previously conflicting
groups, which engaged most of the relevant social actors within the Ebro river basin.
A wide range of stakeholders, who were working independently on their own individual
activities, started building a new crosscutting social movement, which was named the
‘New Water Culture’. This conflict exemplifies how an external pressure that threatens
the whole system in which even conflicting agents operate may be the trigger for a social
re-organisation that leads to the creation of new institutions to cope with that threat
(Tàbara and Ilhan, 2007). Among the self-defined goals of this social movement, the aim
has been to move from a traditional management model based on water supply expansion to one of water demand management (FNCA, 2005).

This particular historical context is important for understanding the current changes occurring in Spanish water policy, which to some extent can already be labelled as ‘transitional’. During the evaluation stage of the case study, special emphasis was placed on exploring the role played by culture and in particular the New Water Culture movement in supporting the current transition within the Spanish water management institutions and practices, and how this movement has affected the Ebro River Basin in particular. An exploration of this movement and effects can be found in Tábara and Ilhan (2007).

To summarise, the main lessons learnt from this stage were the following:

- Most current tools and methods that could potentially be useful for ISA are still embedded in traditional scientific, institutional and cultural paradigms, which tend to serve established power interests (the regime), and therefore are not transition oriented. These established tools and methods are neither multi-level, nor multi-domain. This creates great difficulties if they are to be used for ISA purposes and to explore and support transitions. To carry out ISA, more appropriate tools and methods need to be developed and used in participatory processes that link to scientific and social-cultural contexts of action. However, such tools and methods as well as the attendant mind frames and practices do not exist and need to be developed in parallel with the attempt to carry out ISA and through a process of co-production between tool developers and users.

- ISA involves integrating knowledge, values and worldviews to provide a meaningful and empowering narrative to deal with, communicate, and assess complexity under alternative structuring paradigms in order to support sustainability transitions. ISA cannot lead or trigger transitions unless it is placed in an appropriate context of action that includes agents and stakeholders.

- New ISA tools should help identify the dominant drivers of change that are capable of triggering a transition; for example, the effect of agents’ interactions regarding biophysical thresholds and cultural shifts. They should help to explore different alternative pathways based on different normative criteria; for example, concepts of basic threshold needs and the implications for sharing of scarce resources. New ISA tools should also be much more explicit in representing power and its conditions for change.

- Finally, an important lesson learned from this experience is that it reinforces learning from analogous scientific efforts concerning complex issue domains; i.e., it is important first to focus on a ‘desired future’ in a way that this can be used to develop pathways that can then be used to explore alternative means to these ends.

Transitions in the domain of water may occur in the first place without ISA. Our research explored a possible transition that may be occurring in the Spanish water policy domain and the key role played by cultural shifts as a trigger for network formation and sustainability transformation. However, ISA tools and methods can be developed to manage and frame possible transitions in a more robust way, so they might survive and become stronger in the medium- and long-term. This case study has aimed to do this
using the general World Cellular Framework to support processes of sustainability learning and social learning.

6 Conclusion

In this paper we have reported the process of development and application of a first iteration of Integrated Sustainability Assessment for the case of water by focusing on a particular river basin located in the North-East of Iberia. Being such a novel approach both in developing and using new tools and methods, several factors seem to have influenced the opportunities as well as the constraints of successfully implementing it in this applications context. Some factors relate, on the one hand, to the degree of commitment of scientists and stakeholders to developing new transformative approaches to science and policy and, on the other hand, to the actual capacity of scientists and practitioners to develop new tools and methods and of using them in a timely-enough way for these to have an effect on the institutional and ecological contexts in which they are applied. While it is difficult to maintain engagement of stakeholders during long periods of time, it is also difficult to develop new interdisciplinary and integrated modelling tools when both new ideas about the content and of the actual process of ISA are being developed at the same time. Future research may be able to further analyse these factors and how they can be managed in practice. This paper is necessarily now limited to more descriptive purposes. For that reason, and to clarify the process followed in our case study Figure 5 depicts the stages and content regarding the application of the ISA template to the Ebro River Basin.

Figure 5 Process and content of ISA in the Ebro River Basin
ISA involves a process of *knowledge fusion*, in which facts and values as well as different worldviews and belief system compete but also need to be bridged in a transformative, open, and balanced dialogue. Such a process needs to come up with meaningful and empowering narratives capable of being used to communicate effectively and to assess complexity under alternative structuring paradigms to *support* sustainability transitions. New ISA tools should help identify the dominant drivers of change that are capable of triggering a transition; for example, the effect of agents’ interactions regarding biophysical thresholds and cultural shifts. Our experience in this case study reinforces earlier findings about the need in the visioning phase to emphasise the important role of a ‘desired future’ and to separately handle issues concerning how such a future might be realised through experiments with scenarios and pathways in the experimenting phase.

The lack of systemic analytical methods and tools able to tackle persistent problems of unsustainable development and capable of integrating social, institutional and cultural dimensions provided the rationale for the work of the MATISSE project. Most expert knowledge (scientific and technical) addresses environmental changes mainly by focussing on their final and separate effects rather than dealing with the network of relationships between their ultimate causes and their systemic influences on the global socio-ecological system. The MATISSE project is not only concerned with improving understanding of the systemic implications of the continuously-evolving concept of ‘sustainable development’, but also with exploring the basis for an operational integration of sustainability into policy processes and structures to support transformation. In this sense, the MATISSE project adopted to a certain extent a perspective akin to, albeit critical of, the current discussions on ‘mode-II’ science insofar as it aims at providing useful knowledge in its context of application, hence socially distributed and socially robust knowledge that stems from a close communication with stakeholders (Muller, 2003; Gibbons et al., 1994; Nowotny et al., 2001). We understand that sustainability knowledge must aim at meeting the criterion of ‘strong contextualisation’, although, at the same time, must be able to inform and integrate the knowledge and lessons learnt from external sources and other contexts and domains.

From our research in the Ebro it is clear that tools and methods need to be co-developed at the same time as applying ISA. In this way, and despite the lack of adequate tools in the first ISA iteration, our stakeholders saw sustainability as a situation in which relevant agents continuously learn to collaborate for the common good. This does not mean that all actors have the same set of goals and interests that drive their actions, or that all of them share the same worldviews and ideas about the future. Rather, it means that the different views of the future are not necessarily completely at odds with each other, and that a certain degree of complementary and of positive synergies can be found among them within a minimal common understanding of the problem situation; i.e., about what the problem is, but not necessarily about what we need to do about it. This can be captured by striving for a long-term vision of a sustainable future that captures the essence of those values that are shared. In our research so far in the context of the Ebro case study, a ‘socio-institutional’ vision of sustainability was contrasted with a ‘technical-expert’ vision, indicating that these will now need to be integrated so that we might arrive at a single vision with clear operational definition, both in physical and practical terms.
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References


Notes

1 However, it is important to note that ISA is interested at looking at the possibilities for a larger transition or institutional or regime change, and not only at improving or changing conditions at local or community level. See also Hare et al. (2006).

2 At this first meeting, these were not explicitly articulated, although they were implicitly related to improving the management and rationalisation of resource uses.

3 As extracted from notes made during the workshop. Note here that the concept of ‘re-education’ or new education, argued by this participant, may be interpreted in a broad sense including new ways of learning and engaging people in educational processes.

4 It is worth noting that such threats which operate as triggers of transition are not simply a biophysical threat, but mostly an institutional one, or more specifically a biophysical threat mediated by social institutions (in this case political institutions). Hence, more research in needed to understand what types of trigger start sustainability transitions and under what conditions these develop in the first place (see Tàbara and Ilhan, 2007).