Original Articles

Bringing ecosystem services indicators into spatial planning practice: Lessons from collaborative development of a web-based visualization platform

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Abstract

Considerable efforts are made to integrate ecosystem services (ES) indicators into spatial planning practice. Although a lot of decision support systems already provide helpful functionalities, they are not yet integrated into everyday decision-making, mainly because they do not readily fit into planning processes in practice. There is an increasing awareness that the development should foster collaboration between interdisciplinary researchers and the end users of the tools to secure their suitability for such planning processes. Hence, user-oriented research and experimenting is seen as the appropriate approach for getting the tools ready for practice. Guidelines for conducting such processes are yet missing. Here, we contribute to the development of such guidelines by means of a practical case study. The focus is placed on how transdisciplinary (TD) research on spatial decision support systems should be designed for the integration of ES indicators into planning practice. In a TD project, a web-based visualization platform with indicators of relevant ES was developed to support municipalities of the Canton of Zurich, Switzerland, in assigning adequate watercourse corridors according to the revised Swiss Waters Protection Act. A preliminary as well as an enhanced version of the platform prototype were demonstrated to different actors for evaluating the platform's readiness for practice. We assessed the process design and the quality of the product in a discursive manner. Thereby, we implemented a set of assessment criteria derived from literature and adapted them to the case study at hand for the analysis of empirical material (participant lists, project schedule, meeting minutes and observation protocols). Finally, we discussed the lessons learned on developing significant ES indicators and their visualization and the conclusions drawn with respect to ensuring the quality of the platform development process. The results show that conceptualizing the ES indicators in strong collaboration with practice representatives increased their relevance to the actors' needs and therefore their legitimacy. Providing interfaces for collaboratively translating practical approaches into scientific models is, thus, crucial for the development of significant indicators. Furthermore, specifying the purpose of the visualization platform in planning processes requires prototyping and iterative conceptualization, because practice actors need concrete examples to express their specific demands. This also requires that the concept of developing the ES indicators and the spatial decision support systems should be treated rather as an open working paper than as a final document agreed on in the first collaboration phase. Hence, time scheduling and occupying skilled project managers for this iterative process should be taken seriously.

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1. Introduction

The growing attention of science and practice to ecosystem services (ES) has led to an increased interest in both the public and private sectors for approaches to develop and apply ES indicators in real-world decision-making (Daily et al., 2009; Ruckelshaus et al., 2013). ES are defined as goods and services provided by ecosystems,
which contribute to human well-being, ranging from provisioning (e.g., food, fresh water) and regulating (e.g., water regulation) to cultural (e.g., recreational experiences) and supporting services (e.g., habitat for plant and animal species) (MA, 2005; de Groot et al., 2010). Several decision support systems are evolving for integrating ES into planning processes (Bagstad et al., 2013), i.e., interactive, computer-based tools, which help decision makers to visualize, compare, and consider trade-offs among many ecological, social, and economic values (Labiosa et al., 2013). Although a lot of these systems already provide helpful functionalities, they are not yet integrated into everyday decision-making, because they do not readily fit into existing planning processes (de Groot et al., 2010; Bagstad et al., 2013).

In order to transform current landscape patterns into more sustainable ones, the collaboration of science and a variety of public and private stakeholders is seen as key (Healey, 2007; Scholz, 2011; Steinitz, 2012). Thereby, the transfer of the relevant information to all stakeholders in a credible and comprehensible manner is the essential prerequisite for successful collaboration processes (Wissen et al., 2008). In participatory workshop settings, particularly GIS-based landscape visualizations have proved to be valuable communication and information media for different planning tasks (Salter et al., 2009; Schroth et al., 2011; Wissen Hayek, 2011). Furthermore, besides a sufficiently large set of GIS-tools that can support planning and design, GIS-tools are increasingly offered as participatory web platforms, and designing solutions is becoming more and more a rather collaborative effort than an expert task (Batty, 2013). Most recently, different frameworks and prototypes of web-based visualization platforms were presented which should facilitate the collaboration of heterogeneous stakeholder groups by providing information on possible impacts of certain demands for ES on the fulfillment of other demands (e.g., Klein et al., 2013; Grêt-Regamey et al., 2013). However, the development of such web-based platforms should not only foster the collaboration between GIS-modelers and interdisciplinary researchers but also with the end users of the tools to secure that the platforms actually provide helpful decision support for planning processes (Cook and Spray, 2012; Bagstad et al., 2013).

User-oriented research and experimenting is seen as the appropriate approach for getting the tools ready for practice (Daly et al., 2009). Yet, there are only few studies that assess the application of tools for quantifying biodiversity and ES in real-world decision-making and provide preliminary guidelines as basis for accelerating the development of effective tools (e.g., Ruckelshaus et al., 2013). Thereby, the quality of the system or platform development process is at least as important as the (technical) decision support system itself (Cash et al., 2003).

Approaches which are aiming at a co-production of practical outcomes that can be applied in a social or environmental context for problem solving, can be attributed to transdisciplinary (TD) research (Wickson et al., 2006; Pohl, 2008). However, the boundaries between applied and TD research types are gradual with regards to the distinguishing characteristics and the methodology (Hirsch Hadorn et al., 2006). There is neither a common definition nor methodology of TD research, but patterns of common characteristics can be identified (Jahn et al., 2012; Thompson Klein, 2013). According to Pohl (2005, 2011), important distinguishing characteristics of TD research are, that the researchers have to frame, analyze, and process a societal problem in a manner that (1) its complexity is grasped, (2) the diverse perspectives of science and society are addressed, and (3) that it links abstract and case-specific knowledge in order to (4) produce practically relevant knowledge according to the stakeholders’ value systems. A collaboration of academic as well as non-academic stakeholders and a process of mutual learning are necessary to tackle the four issues (Wickson et al., 2006; Pohl, 2005, 2011; Hirsch Hadorn et al., 2006). Since the process is characterized by science-practice collaboration and mutual learning, the usability of results of this process should be evaluated in a recurrent manner (Pohl, 2005; Hirsch Hadorn et al., 2006). Yet the development of guidelines for designing and evaluating TD research are still in its infancy (Carew and Wickson, 2010; Lang et al., 2012). Important sources for principles and concepts for design and quality evaluation of TD research processes and products are primarily case studies (Klein, 2008; Thompson Klein, 2013; Pohl, 2011; Seppelt et al., 2012; Staußacher et al., 2012).

Here, we contribute to the development of guidelines by means of a practical case study. The focus is placed on designing and evaluating the TD research on a web-based visualization platform for the integration of ES into everyday decision-making. We analyze a TD process where the planning task of an ongoing collaborative planning process – the designation of watercourse corridors in the Canton of Zurich, Switzerland – was the starting point for collaborations between academic researchers and diverse actors from practice. The TD research aimed at the development of a web-based visualization platform for taking ES indicators of riparian areas and other indicators of socio-economic demands into account in the design of watercourse corridors at the local level. The intended purpose of the platform was to support discussion and balance diverse actors’ conflicting interests in solution development. A preliminary as well as an enhanced version of a prototype were demonstrated to different actor groups for evaluation of the readiness of the platform for practice purposes. Here, we analyze empirical material of this case study, implementing a set of assessment criteria derived from literature. We discuss the lessons learned on how to develop significant ES indicators and to ensure the quality of the platform development process as well as the platform’s decision support function in practice. We conclude by reflecting on requirements and implications of the development of spatial decision support systems integrating ES indicators into planning practice by implementing TD approaches.

2. Methods

2.1. Case study: Collaborative development of a web-based visualization platform

Riparian areas serve as habitat for plants and animals, as space for recreation and identification for the people, they provide fresh water and protect against floodwater or are economic production areas (Hauser et al., 2011). These services of the riparian areas contribute to human well-being (Millennium Ecosystem Assessment, 2005). Since physical modification of rivers through human activities has degraded the provision of these services significantly all over the world, there are increasing political activities considering river rehabilitation (Gilvear et al., 2013). In Switzerland, about 42% of the watercourses do not provide the services sufficiently (Zeh Weissmann et al., 2009), and the recent revision of the Waters Protection Act (GSchG, 2014) from the 1st of January 2011 obligates the cantons, therefore, to define adequate corridors for watercourses. These corridors shall provide an area for enhancing or restoring the supply of the ES. The process of their designation should be characterized by an informed trade-off decision-making of different actors’ economic, ecological, and social demands (Oberle, 2011).

The Canton of Zurich started a collaborative process for the implementation of the Waters Protection Act. The goal of this broad-based participatory process was to define principles, approaches, and responsibilities for designating the watercourse corridors at municipality level. Furthermore, the canton wanted to provide the municipalities with spatial decision support tools. Particular tools were needed for effectively communicating and deliberating the spatial priorities of the provision of certain ES of
2.2. Assessing the process and product of platform development: The methodological approach

Due to the multidimensionality and context-specific nature of TD research, a universal method for its evaluation seems inappropriate (Klein, 2008). Instead, frameworks of generic principles and quality criteria for evaluation provide a basis for assembling coherent assessment criteria that suit the project setting and the research objectives of a concrete TD case study (Bergmann et al., 2005; Klein, 2008; Lang et al., 2012; Wicken et al., 2006). In the following, we state such generic principles, which we used for the evaluation of the TD research design on the web-based visualization platform. These principles were used to reflect on how to foster the integration of ES into everyday decision-making. In favor of a concise presentation of the analysis results, we selected the, in our view, most important principles concerning the research question in this paper: Implementing TD approaches, which are the requirements regarding the process design and the product of developing spatial decision support systems for integrating ES indicators into planning practice?

A major focus in TD research for the purpose of product and technology development is laid on the involvement of stakeholders in product development (Thompson Klein, 2013). With regard to sustainability indicator development, Rametsteiner et al. (2011) stress that the socio-political dimension of the process is as important as the technical development process, because the indicators are not only means to structure and communicate information but also the result of politically normative decisions on the relative importance of an issue. Hence, two aspects are of major relevance for the analysis of the process (Rametsteiner et al., 2011): (1) the diversity of participants and (2) the learning of actors with a focus on the problems and instruments related to dealing with the issues in question. The analysis should, thus, focus on how participants are selected, how they interact, and how decisions are made during the development of indicators as well as how learning of the participants is being enabled. Furthermore, the roles of the scientists and the other actors in the different phases of the development process should be made explicit in order to identify and specify their appropriate roles in such processes.

Further, effective implementation of decision support systems that link knowledge to action require, in particular, active communication between the science and the practice communities, translation of information to improve mutual understanding, and active mediation of multiple stakeholders’ conflicting views on how to achieve saliency (relevance to decision-making), legitimacy (information production is fair, unbiased, and respects divergent values), and credibility (the scientific adequacy of evidence and arguments are based on the methods and tools) of the TD research product (Cash et al., 2003). This integration of different types of knowledge, the problem- or product-oriented integration of knowledge, and the social integration of various actors with different interests, roles, and practices of communication constitute a major challenge in TD research (Jahn et al., 2012). Fostering communication and the integration of knowledge can be substantially influenced by the management and organization of the TD collaboration (Klein, 2008). In addition to the organizational structure of the interaction, also the dynamic of how the research process is developing should be taken into account, e.g., how the methodology is evolving over the course of the project in response to the feedback or changing perspectives of stakeholders (Wicken et al., 2006). An ideal TD process can be structured into a sequence of three phases: (1) problem framing and teambuilding, (2) co-creation of solution-oriented transferable knowledge, and (3) (re-)integrating and applying the produced knowledge in both scientific and societal practice (Lang et al., 2012). However, rather than following a linear course, the process often goes through a number of iteration loops of individual phases and the entire sequence. Hence, although the project chronology has proven helpful and transparent for evaluating projects, also a theme-oriented evaluation focusing on essential aspects of TD research projects can be useful for gaining a deeper understanding of the process and the steps toward knowledge integration (Bergmann et al., 2005).

Finally, TD research projects should conduct a reflection not only of the process, but also of the product (Wicken et al., 2006). Particularly the product’s practical relevance should be assessed (Bergmann et al., 2005; Lang et al., 2012). Important quality criteria in the context of the case study were the credibility, saliency, and legitimacy of indicators and the usability of the web-based visualization platform.

Based on the principles discussed above, themes and correlating characteristics by which the case study was analyzed were defined as shown in Table 1. Diverse empirical material was analyzed including the project schedule, minutes, and participant lists from meetings of the scientists with different actors throughout the development process, interim and final documents of the concept of the visualization platform, preparatory documents of the demonstration of prototypes of the visualization platform, protocols of the feedback from potential user groups of the visualization platform, and protocols of observations during the prototype demonstrations. Additionally, the authors were personally involved in the process in a leading role and in the technical development of the

<table>
<thead>
<tr>
<th>Theme</th>
<th>Characteristics assessed</th>
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<tr>
<td>1. Actors and their tasks/roles</td>
<td>Groups of actors and their tasks and roles in the project</td>
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<tr>
<td>2. Organization of the collaboration</td>
<td>Organizational structure and dynamic of the process development</td>
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<tr>
<td>3. Knowledge integration</td>
<td>Interaction of actors to integrate different types of knowledge</td>
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<tr>
<td>4. Practical relevance of the product</td>
<td>Credibility, saliency, and legitimacy of indicators and readiness of the visualization platform for its purpose in practice</td>
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visualization platform. They conducted participant observation and self-reflection during all stages of the development process.

The analysis was carried out in a discursive manner by the scientists who were involved in the project. The scientists analyzed the different themes first on their own and then discussed the individual results together and documented their insights.

3. Results: The process and product of platform development

3.1. Actors and their tasks/roles

Actors from science and practice collaborated in the development of the visualization platform. Following Bergmann et al. (2005), the participants from practice were divided into three groups – practice partners, practice representatives, and practice actors – which had different roles in the project (Table 2). Due to the overall project setup, i.e., that the pilot project was part of an on-going collaborative planning process (see Section 2.1), the participants in the development of the platform were already defined by the practice partner at the beginning of the project.

The first group comprised one practice partner, who was the head of a section of the Cantonal Agency of Hydraulic Engineering and Planning. He managed the major project “Implementation of the Waters Protection Act in the Canton of Zurich” and was the contracting body for the science partner. Thus, he was also in charge of contributing to and deciding on the overall direction of the pilot project “Platform Development”, as it was part of his major project. Due to his decision, the participants of the major project were also participants in the sub-project, since they were already familiar with the task and the multiple conflicts of interests coming along with the designation of watercourse corridors.

The second group of participants from practice represented a group of actors with certain interests related to their professional field (e.g., interest in agricultural direct payments, nature protection, or protection of private real-estate property). The scientists collaborated directly with these practice representatives, who provided relevant information for the indicator development and visualization. Whereas in the first part of the project they were rather passively involved, limited to information provision, this group became an active partner in the second part. Practice representatives intensively collaborated with research scientists in the conceptualization and specification of ES indicator models.

The third group comprised the practice actors, which were involved in the evaluation of the visualization platform prototypes. They took part in the demonstration of the first and the second version of the prototype and had the opportunity to individually test it to provide their feedback on its assumed suitability for implementation in practice.

Research scientists with a background in landscape and environmental planning, GIS-based visualization, and graphic or web design were required for the technical development of the visualization platform. They were chosen when setting up the initial project concept. The role of the science partner was to manage the process of platform development and conduct its technical implementation.

3.2. Organization of the collaboration

Fig. 1 presents the project chronology of the prototype development. The whole process can be divided into two major parts, the development of the first and of the second version of the prototype. Each of these parts comprises the three phases of TD research projects (problem framing and teambuilding, co-creation of knowledge, and application of results; see Section 2.2). However, whereas in part 1 the process showed rather chronological sequences of the phases, in the second part the phase of problem framing and teambuilding and the phase of co-creation of knowledge were mixed. In the first part, the active collaboration took place primarily between the science and the practice partner. Major milestones were agreed concepts of the platform’s contents and its application, which were suggested by the science partner. The practice partner criticized the suggestions, and this feedback was used for further concept adaptation by the science partner. Practice representatives were only involved in the project in form of delivering GIS data and information required for calculating the indicators agreed on. Further, in a pretest of the platform demonstration they were asked to consult with regard to setting up the program for the application of the prototype. Practice representatives and practice actors were then invited to the demonstration to give feedback on the platform’s suitability for practice. Additionally, they received the link to the online platform for individual exploration and further feedback provision.

In the second part, first, the project concept was revised collaboratively by the science and the practice partner, based on the feedback of the practice representatives and practice actors gathered on the prototype version 1. However, this time the concept was treated as a working document, because it was agreed that the required platform contents and indicator specifications had to evolve from the collaboration of the science partners with the practice partner and the practice representatives of relevant professional fields (e.g., agriculture and nature protection). Thus, new teams had to be built, and the co-creation of knowledge was characterized by several meetings and discussions by phone and e-mail between science and practice representatives, leading to a common specification of the GIS-models for indicator calculation. In the course of this process, the concept of the platform was iteratively revised and adapted. The final concept of the platform’s content, functionality, and methods for indicator calculation were only available at the end of the pilot project. The second version of the prototype was again demonstrated to the practice partner, representatives, and actors, who also after this event could individually test the prototype for a longer period. Their feedback was again used for a reflection on the usability of the prototype in practice.

3.3. Knowledge integration

The integration of knowledge from the participating scientific and practice fields was driven by the orientation on the product. The science partners contributed their knowledge and technical skills to modeling spatial indicators and visualizing the results with a web-based platform. They particularly took care that for the calculation of the design alternatives of the watercourse corridors and of the indicators generic GIS-models were set up, which can be applied with the cantonal GIS-data generally available to all municipalities in the Canton of Zurich. In the first part of the project, they also provided knowledge on specific ES indicators, such as the degree of supply of people with public green space indicating the watercourse corridor’s potential provision of recreational services. However, the model for indicator calculation was based on an existing method developed by the City of Zurich (Stadt Zürich, 2014). All other contents, such as the design alternatives of watercourse corridors according to specific criteria, the prioritization of areas for river revitalization, or costs of revitalization, were defined by the practice partner and practice representatives. In addition, they provided the empirical knowledge on the practice procedures and the target knowledge on the purpose for implementation, which guided the science partners in preparing customized sets of information in the visualization platform. For example, for the urban pilot municipality “Dietikon” (prototype version 1) basic data of the
municipality’s status quo (e.g., density of the built-up area and the indicator on the provision of the recreational service) was assembled with possible alternative designs of the watercourse corridors and indicators on the resulting costs, buildings in the corridors affected by certain restrictions, and the effect of the corridors on the recreational service. The design alternatives were basically defined by specifications of the Swiss Waters Protection Ordinance (GSchV, 2014). Additionally, the pilot municipality was encouraged to adapt these alternatives to the local conditions in order to reduce conflicts between different actors’ demands.

During the demonstration of the first prototype, the practice actors learned about the potentials to implement the visualization platform into the procedure of designating the watercourse corridors. For example, the ES indicator regarding recreational service showed that employees in the city center of Dietikon are currently insufficiently served with public green space (Fig. 2). A watercourse corridor design alternative, which is based on the flood water protection curve according to the Swiss Waters Protection Ordinance (GSchV, 2014), would not only serve the purpose of flood water retention, but also recreational purposes along the river. In case of good green space design, these areas could provide multifunctional and attractive green spaces, significantly enhancing the current recreational situation. Since the city center is densely built, however, this design alternative causes a conflict with the owners of real-estate situated within this watercourse corridor, who are, hence, facing restrictions placed on property use. The ES indicator shows the impact on the recreational service in case of another design alternative, where the watercourse corridor is reduced to

### Table 2

List of participating actor groups from science and practice with information on their scientific fields or professions in practice. The number of people (N) involved and the task or role of the respective actor group in the first and the second part of the project are given.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td></td>
<td>N Task/role in the project</td>
<td>N Task/role in the project</td>
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<tr>
<td>Science Partners:</td>
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<td></td>
</tr>
<tr>
<td>- GIS-/Visualization Experts</td>
<td>3 - Coordination of the project Platform development</td>
<td>3 - The same as in Part 1.</td>
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<tr>
<td>- Graphic/Web Designer</td>
<td>1 - Technical development</td>
<td>1 - The same as in Part 1.</td>
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<tr>
<td>Practice Partners who took part in the project by making their field of activity accessible as a pilot field:</td>
<td></td>
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<tr>
<td>- Cantonal Agency of Hydraulic Engineering and Planning</td>
<td>1 - Coordination of the project Implementation river protection act</td>
<td>1 - The same as in Part 1.</td>
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<td>Practice Representatives, who took part in the research project on behalf of a group of actors:</td>
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<td>- Cantonal Agency of Hydraulic Engineering and Planning</td>
<td>4 - Providing information on relevant indicators</td>
<td>4 - Providing information on relevant indicators</td>
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<tr>
<td>- Planners of pilot municipalities</td>
<td>1 - Providing current data</td>
<td>1 - - Providing current data</td>
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<tr>
<td>- Consultant for cultural heritage protection and urban planning</td>
<td>1 - Providing feedback on the platform</td>
<td>1 - Providing feedback on the platform</td>
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<td>- Cantonal Agency of Agriculture</td>
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<tr>
<td>- Cantonal Agency of Nature Protection</td>
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<tr>
<td>- Consultant for the agricultural direct payment system</td>
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<td>Practice Actors who are potential end users of the product, but who were not directly involved in the development:</td>
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<tr>
<td>- Representatives of cantonal agencies:</td>
<td>26 - Participation in the advisory board meeting, in which the first version of the prototype was demonstrated</td>
<td>10 - Participation in the expert meeting in which the second version of the prototype was demonstrated</td>
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<td>Hydraulic Engineering and Planning; Legal Service: Real Estate Office; Spatial Planning; Cultural Heritage Protection; Agriculture; Nature Protection; Soil Protection</td>
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<td>- Planners and representatives of four pilot municipalities</td>
<td>17 - Feedback on the usability of the prototype for communicating and trade-off decision-making in the designation of watercourse corridors</td>
<td>1 - Feedback on the usability and potential for implementation of the prototype, especially in the Cantonal Agency of Hydraulic Engineering and Planning for communicating and trade-off decision-making in the designation of watercourse corridors</td>
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<td>- Banking sector and insurance</td>
<td>1 - Suggestions for enhancement with regard to indicators and alternative designs of watercourse corridors in order to meet the practical requirements</td>
<td>1 - Suggestions for enhancement with regard to indicators and alternative designs of watercourse corridors in order to meet the practical requirements</td>
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<td>- Energy companies</td>
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<td>- Fisheries Association (Canton Zurich)</td>
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<tr>
<td>- Municipalities (Association of Public Servants and Administrators and the Association of City Councilors of the Canton of Zurich)</td>
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<td>- Landlords Association Zurich</td>
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<td>- Environmental protection and nature conservation associations</td>
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<td>- Forestry Business Association of the Canton of Zurich</td>
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<tr>
<td>- Association of Farmers of Zurich</td>
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<tr>
<td>- Regional Planning Organization of Zurich</td>
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### Part 1: Prototype Version 1

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<td>Drafting platform concept</td>
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<td>Phase 1 Problem framing</td>
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<td></td>
<td>01</td>
<td>Concept development</td>
</tr>
<tr>
<td></td>
<td>02</td>
<td>Calculation of design alternatives</td>
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<td>03</td>
<td>Calculating design alternatives and indicators</td>
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<td>04</td>
<td>Internal testing and adaptation of indicator visualization</td>
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<td></td>
<td>05</td>
<td>Further developing of GIS models for indicator calculation</td>
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<td>06</td>
<td>Final pretesting of indicator visualization</td>
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<td>Final testing of the prototype demonstration</td>
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<td>08</td>
<td>Assessment of the prototype demonstration</td>
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<td>09</td>
<td>Application and feedback collection</td>
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<td></td>
<td>10</td>
<td>Revising platform concept and design</td>
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<td>Finalizing the prototype demonstration</td>
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<td>Prototype demonstration and feedback collection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Internal pretest of the prototype demonstration</td>
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<tr>
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<td>01</td>
<td>Reflecting on the quality of the prototype for practice and science</td>
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### Part 2: Prototype Version 2

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<td>01</td>
<td>Concept development</td>
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### Categories of activities:
- Concept development
- Construction of the web-based platform
- Application
- Reflection

### Actor groups:
- SP = Science Partner
- PP = Practice Partner
- PR = Practice Representative
- PA = Practice Actor

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**Fig. 1.** Chronology of the procedure of conceptualizing, developing, applying, and revising the two prototypes of the web-based visualization platform. Activities in bold were major milestones of the prototype development. The phases 1–3 are typical of a transdisciplinary research process (see Lang et al., 2012).

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**Fig. 2.** Indicator maps of the provision of the recreational service of public green spaces for the current situation and alternative watercourse corridor designs: Degree of supply of employees with public open space within a walking distance of 200 m (intense green = 100% ≥ 5 m²/employee). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)
administration on agriculture as well as farmers, which were both experts on direct payments, collaborated intensively with the science partners. In this way, the target knowledge of the practice representatives was integrated into the scientific models. The indicators take actual incomes generated on the land parcels in the case study area as basis. Further, they take into account the current and also the possible future agricultural direct payment scheme, which was still under discussion. Hence, the indicators can address questions which the farmers actually have, namely, the impact of watercourse corridors on the current income and on the potential future income if the proposed new direct payment scheme would be enacted (Figs. 3 and 4). The science and practice partners mutually decided to prepare indicators of the ES service of habitat provision and of cultural services also in monetary terms. The habitat provision can be increased in the agricultural area with larger areas of extensive management. Since the farmers get direct payments for extensive management, the same indicator model as for the production service was applied. The cultural service
was expressed in terms of the willingness of an adult inhabit-
ant to pay for the revitalization as an additional benefit for his
recreation. The amount of money was based on results of a study
conducted in Switzerland (Arnold et al., 2009). The assumptions
and decisions made by the participants actively involved in spec-
ifying the contents and indicators of the platform were document-
ted to make the approach of knowledge integration transparent.
This document was made available for download on the online
platform.

3.4. Practical relevance of the product

Concerning the first version of the prototype, there were rather
diverging opinions on its quality. Some practice actors evaluated
the possibilities of the visualization platform as good, whereas oth-
ers were more skeptical, particularly with regard to the significance
of the ES indicators. These critical actors were primarily experts,
who criticized that their knowledge was not sufficiently integrated
into the selection of relevant indicators and the specification of
models to calculate them. For example, the indicator map on the
 provision of the recreational services was appreciated with differ-
ing degrees of added value by experts of heterogeneous fields.
For some the indicator provided helpful information for a first appraisal
of the watercourse corridors’ effects, for others the indicator was
far too generic. The actors recommended enhancing the definition
of the target group and thus the purpose of the information and the
indicators. The platform, for instance, should be either enhanced to
support specific analysis tasks of the administrations at cantonal
and/or municipality level or it should be prepared to preliminary
suit communication with heterogeneous actors affected by the des-
ignation of watercourse corridors.

In contrast to the first version, the second version of the proto-
type was said to provide a good basis for discussion. For example,
actors mentioned that the platform could support deliberation on
concrete revitalization projects by illustrating synergies between
ES, socioeconomic benefits, and river protection. They were of
the opinion that the platform could communicate these syner-
gies effectively. They thought that this could, in turn, facilitate
the understanding of different actors’ demands and potentially
increase the societal acceptance of certain watercourse corridor
designs. In this way, the platform could possibly mitigate the politi-
cal negotiation process on the designation of watercourse corridors.
However, practice actors pointed out that the platform could only
serve as an overview but not as a consulting tool, e.g., for individual
farms and their business plans. Further, the information provided
was regarded as not sufficiently comprehensive to support the
concrete designation of watercourse corridors. The resulting plat-
form prototype was classified as a hybrid providing an expert level
for individual information exploration and a presentation level
for communicating major findings to stakeholders. However, none
of the levels was regarded as sufficient for the respective pur-
pose. Therefore, the actors recommended to further customize the
platform with regard to its purpose, which also required further
specification.

4. Discussion

We presented the TD case study on the collaborative develop-
ment of a web-based visualization platform to discuss the lessons
learned on integrating significant ES indicators into decision sup-
port systems that are actually useful for planning practice. First, we
identified the role of different actors or actor groups as an impor-
tant aspect in this context. The overall process management led
by the science partner with regard to the scheduling of tasks has
proved to work well. However, due to the dynamic development of
the overall process in the second part of the project, more personal
resources for project management than originally planned had to
be made available. Further, the strong collaboration of science and
practice partners in directing the definition of the content of the
visualization platform was effective, because both partners always
supported the chosen approach and the resulting prototypes. This
created a positive attitude to the development of the platform
and the openness to try out different strategies and approaches.
Thereby, the group of practice representatives had a crucial role
in the definition and specification of ES indicators and respective
GIS-models. However, the collaboration between them and the sci-
ence partners was temporarily difficult, due to delayed delivery
of necessary data. The commitment to collaborate is an important
prerequisite for successful processes of ES indicator development,
which should be obtained as early as possible.

A second insight is that the linear process of concept devel-
opment, implementation, and application did not lead to desired
results in terms of relevant and legitimate ES indicators. In con-
trast, the iterative definition and specification of ES indicators in
the second part of the project was more successful in generating
models and visualizations of the results meaningful for practice
actors. The importance of an iterative science-policy process is a
lesson that also Ruckelshaus et al. (2013) learned from their eval-
uation of case studies. In our case, this iterative and interactive
approach was made possible by the decision to work with an open
concept of the platform’s contents. However, the open concept did
not mean that there was no concept of the indicator and plat-
form development. A draft conceptual framework should serve
as a central reference point for the process of further adaptation
and revision. Furthermore, documenting these steps throughout
the process provided transparency of the whole approach for all
actors and further stakeholders not involved in the collaboration.
The possibility to read about the assumptions and decisions made
can increase the credibility and legitimacy of the ES indicators for
practice actors.

During the different phases of the project, varying types of com-
unication were applied for integrating knowledge about planning
purposes and practices as well as required information into the
scientific specification of the ES indicators and the design of the
visualization platform. These types of communication can be dis-
tinguished with regard to the flow of information and commitment
of science and practice partners (Trutnevye and Stauffacher, 2012).
The communication with the actors from practice ranged from
provision of information only to actual collaboration with two-
way communication on the conceptualization and specification
of indicator models. The latter type of communication was most
effective in terms of knowledge integration. In particular, the ES
indicator on agricultural production was valued by the practice
actors as salient and legitimate indicator. Hence, the expertise of
participants representing a group of actors should be regarded as
key factor for conceptualizing and implementing ES indicators
into practice. Rather than involving all of the participating actors
with high intensity, a targeted collaboration with different actor
groups applying involvement techniques as appropriate, a so-called
functional-dynamic organization (Stauffacher et al., 2012), seems
to be more suitable.

Due to the mutual definition of indicators, criteria of both
science and practice were taken into account to generate the
GIS-models for calculating the indicators. This also ensures cred-
ibility for all collaboration partners (Cash et al., 2003). However,
in our case study, the purpose of the visualization platform was
not defined sufficiently precisely until the end of the project. This
in turn rendered the definition of relevant indicators even more
difficult. In particular, more effective methods are needed for inte-
grating target knowledge on the purpose of ES indicators and
decision support systems in practice. For example, the testing of

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prototypes in actual planning settings in pilot projects could be useful to this end.

Another finding is that the learning process the actors go through is an important component of making ES indicators and their visualization fit for the practice purpose. In the beginning of the project, the practice actors were not able to clearly define their requirements and expectations. For this reason, the purpose of the ES indicators and the target group of the visualization platform were defined rather broadly. With each of the prototypes it became clearer which purposes the visualization platform might probably be helpful for. The prototypes turned out as effective media for successively defining the contents and the functionality of the visualization platform including ES indicators. Bearing in mind that a learning process is required to specify the expected product, it should be iteratively asked throughout the collaboration process and based on concrete indicator examples, what the purpose of the ES indicators is in practice.

Finally, the method for analyzing this case study, based on principles for TD research design and evaluation, supported a structured and systematic discourse. This actually fostered a deeper insight into the process of the ES indicator development in the case study. We recommend taking into account the available principles for TD research not only for the evaluation of TD research projects but also especially for setting up collaborative projects of science and practice partners to secure the quality of the process and its products. Correctly designing the collaboration process is one prerequisite to successfully integrate ES indicators into everyday decision-making. Integrating phases for reflection of the overall process and the quality of the products, as demonstrated in this paper, is therefore very important for enhancing the working of what effective ES indicators and decision support systems for practice purposes are.

5. Conclusions

Our findings have very practical implications for the integration of ES indicators into spatial decision support systems implementing TD approaches. We experienced that when the platform and its ES indicators advanced and the knowledge and understanding of possibilities for information provision increased, the demands of different actors became more concrete and initial ideas could change. Prototyping is, thus, seen as a useful approach, which enables to specify the purpose with practice actors in an iterative manner. In our case, this provided a good basis for a follow-up project, which aims at developing the actual visualization platform of watercourse corridors and relevant indicators of their impact as part of a decision support system for practice. Moreover, the provision of interfaces for the collaborative translation of practical approaches into scientific GIS-models is crucial for the development of significant ES indicators. The commitment of practice representatives to collaborate actively and an open concept that allows trying out different approaches were identified as important prerequisites. The concept of developing the ES indicators and the decision support systems should be treated rather as an open working paper than as a final document. Hence, scheduling of time and occupying project managers with adequate knowledge and management skills for the iterative communication and specification process should be taken seriously.

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