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CO-PRODUCTION OF KNOWLEDGE:

A CONCEPTUAL APPROACH FOR INTEGRATIVE KNOWLEDGE MANAGEMENT IN PLANNING

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Abstract

Sustainable land use needs a manageable nexus of knowledge from planning practice, policy makers, the private economy, and civic society, as well as from scientific research. This is mutually dependent on the communicative and collaborative turn in spatial planning as well as by transdisciplinary research approaches. This paper offers an approach how to organise knowledge management and co-production of knowledge in the context of complex land use decisions. Therefore, a prototype of an internet-based knowledge platform is introduced based on a theoretical reflection of concepts for integrated information and knowledge management, as well as on practical experiences derived from a German case study. We conclude that sustainable land use requires Planning Support Systems (PSS) that combine transdisciplinary perspectives in order to co-produce robust knowledge. This also implies a transdisciplinary design of PSS. Challenges of implementation are discussed and further research is specified.

Keywords

Knowledge management, planning support systems, transdisciplinary research, land use change, decision-making capacity.

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1. Introduction

Spatial planning is integrative and interdisciplinary in nature (Salet, 2014). However, new land use drivers like climate change, the renewable energy supply, international interdependencies of resource markets, and demographic changes increase the complexity of handling the manifold demands on land (Müller and Munroe, 2014). Land use change and different land use demands can evoke a number of land use conflicts (amongst others, von der Dunk et al., 2011; Mann and Jeanneaux, 2009; Goetz, Shortle, and Bergstrom, 2005). Incompatible interests related to certain land-use units can cause negative social (social power imbalances), economic (decrease of agricultural productivity), and environmental impacts (loss of biodiversity due to land fragmentation), delaying the implementation of the normative goal of sustainable development. According to this complex environment for planning processes, spatial planning has to develop strategies dealing with high levels of uncertainty (unpredictable spatial developments), disagreement (conflicting aims), and distributed capacities (multi-stakeholder environments) (Hummelbrunner and Jones, 2013, p.2).

In response to these challenges, manifold demands on spatial planning are defined. For instance, the consideration of functional interdependencies requires a changing perspective from site-specific management to a more integrative perspective on different land use functions. In consequence, spatial planning that meets real-world problems and copes adequately with multi-dimensional questions of sustainable land use should coordinate and integrate spatial, sector-oriented, and temporal aspects (respecting intra- and inter-generational fairness) and cover the debate about norms and visions driving policy-making and decision processes (Cash et al., 2006a). Furthermore, spatial planning should respect functional perspectives of spatial development (Healey, 2004; Allmendinger et al., 2015) and evaluate impacts on and of land use (Faludi, 2000; Davoudi, 2006). Finally, it has to organise transdisciplinary processes, including different academic, and professional domains as well as civil society (Wickson, Carew, and Russell, 2006; Lang et al., 2012; Zscheischler, Rogga, and Weith, 2014). These demands on spatial planning are reflected by the communicative and collaborative turn from technical rationality, for instance (de Roo and Silva, 2010).

Handling land use and particularly land resources in a sustainable way will only be possible if all actors not only develop awareness for the problems involved, but are also prepared to generate, share, and actually put knowledge into practice (Cash et al., 2003; Campbell, 2012). This complexity – seen as a window of opportunity (de Roo and Silva, 2010) – defines new requirements in managing the different knowledge stocks. Cornell et al. (2013) point out the considerable relevance of the quality and validity of knowledge systems in the context of sustainability research. Quality and validity

> depend on ensuring plurality, transparency and independence; furthermore, sustainability scientists have a responsibility to collaborate openly in knowledge co-production and its translation to action with other social actors within knowledge systems (Cornell et al., p.61).

Thus, knowledge management forms an essential component for future planning and land management (Davoudi, 2015). During the last decade, an elaborated system of participation and information management in spatial planning has emerged. This is also reflected in planning theories (Friedmann, 1987; Healey, 1996; Allmendinger and Tewdwr-Jones, 2002; Rydin, 2007) and changes in planning traditions (Ibert, 2003; Vonk, 2006; Laurian and Shaw, 2008). Hence, dealing with communication strategies and knowledge management is compulsory for the daily work of planners. This is represented in a variety of educational books about planning (e.g. Cullingworth et al., 2015 for the UK; Fürst and Scholles, 2008 for Germany).

Spatial planning uses different approaches for generating and organising knowledge – formal as well as non-formal types – such as sectoral and integrated plans, reports and comments, participation procedures, information events, or tools for decision support. However, instruments like these focus mainly on sectoral, short-term questions like planning permission procedures for bypass roads. Often, participatory forms of planning are predominantly discussed in the urban planning context (including Rubenstein-Montano, 2000; Saarloos et al., 2008; te Brömmelstroet, 2012). However, instruments of knowledge management addressing complex questions of sustainable land use and spatial development are rare.

Planning Support Systems (PSS) have proved to be adequate instruments to merge complex stocks of knowledge fostering sustainable spatial developments (Vonk, 2006). They have significantly grown in importance, especially thanks to the enormous progress in computer-related hardware and software that was also eliciting the transformation to knowledge-based society. Properly understood, PSS are aimed at supporting planning processes, managing stocks of knowledge, and generally improving planning regarding its results (te Brömmelstroet, 2013, p.300). Pelzer et al. (2014, p.24) stress that 'communication and collaboration have become critical components in the role of planning support'. However, low implementation rates of PSS in daily planning practice are still evident (te Brömmelstroet, 2012, p.96). In particular, gaps in PSS exist regarding the function of communication and knowledge management (Vonk, 2006).

The lack of knowledge management approaches is not solely a problem in spatial planning but in sustainability science on the whole. Miller et al. (2014, p.244) underline the current lack of knowledge management in sustainability research. Further, Kajikawa, Tacoa, and Yamaguchi (2014, p.438) stress the lack of transdisciplinary sustainability research that still deserves 'design principles'. Thus, current questions in sustainability science focus on the appropriate role of science – and especially of knowledge management – in contributing to action and decision-making for sustainability (Miller et al., 2014, p.244; Cornell et al., 2013).

The aim of the paper is to discuss the meaning of knowledge management in a highly complex planning context such as sustainable land use and land management. To this end, we present a conceptual approach in how to organise knowledge management and co-production of knowledge in the context of complex land use decisions. A concept for the further development of Planning Support Systems (PSS) from an informational to a communicating character will be introduced and discussed against the background of a transdisciplinary perspective and spatial development. Thus, the paper provides conceptual contributions to link knowledge from different sources, rationalities, spatial scales and channels, aiming at strengthening the depth of planning knowledge (Salet, 2014) and contributing to the development of robust[1] policy solutions (Scholz, 2015). As such, the paper combines discourses about knowledge management in the context of spatial planning – and particularly using PSS – as well as sustainability research.

According to these aims, the paper addresses the following research questions:

- Q1: How can knowledge management be established for supporting decision-making capacity?
- Q2: What framework is suitable for the co-production of spatial planning-related knowledge?
- Q3: How can knowledge management be organised in complex planning processes?
- Q4: What is the added value of integrated knowledge management for planning support systems?

First, we define the conceptual framework of knowledge management and PSS in the context of sustainable land management. Second, we present the concept and design of an information and communication technology based (ICT-based) knowledge platform that is already implemented and point out the methodological approach. Third, the approach is discussed with respect to its implementation in planning practice. Finally, we conclude with proposals for the further development of PSS.

2. Key Issues of Knowledge Management in Planning

2.1. Knowledge and Knowledge Management

On the way to a global knowledge society (Organisation for Economic Co-operation and Development [OECD], 1996; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2005), questions

1 According to Scholz (2015), a 'socially robust orientation: 1) meets science state of the art scientific knowledge, 2) has the potential to attract consensus, and thus must be understandable by all stakeholder groups, 3) acknowledges the uncertainties and incompleteness inherent in any type of knowledge about processes of the universe, 4) generates processes of knowledge integration of different types of epistemics (e.g. scientific and experiential knowledge, utilizing and relating disciplinary knowledge from the social, natural, and engineering sciences), 5) considers the constraints given by the context both of generating and utilizing knowledge'.

about what knowledge management is and how the knowledge production process can be organised to promote knowledge sharing are becoming increasingly relevant every day. These questions are of major importance in the knowledge-based economy (OECD, 1996; North and Kumta, 2014) as well as in current research on sustainable development (Pohl et al., 2010) and particularly in spatial planning (Rubenstein-Montano, 2000; Vonk, 2006). Many definitions and models of knowledge management exist, representing different contexts, e.g. economic organisations, academic institutions or institutions of policy-making (Anand and Singh, 2011). The authors define knowledge management as the purposeful and strategic influence of activities and processes aiming at an effective transfer of tacit knowledge (embodied knowledge) into explicit knowledge (disembodied knowledge). The chief aim of knowledge management in planning is to provide access to explicit knowledge for participants and, subsequently, the successful utilisation and implementation of knowledge using collaborative learning processes in order to enhance decision-making for managing land use change. Information management (also known as information and data management) differs from this and encompasses the processes for the capture, selection, categorisation, indexing, retention and distribution of information (Kaiser, Köhler, and Weith, 2016).

According to the knowledge ladder by North and Kumta (2014), three action fields of information and knowledge management can be derived (see Figure 1). Information and data management is the basis for knowledge management. Strategic knowledge management traverses the knowledge ladder in a top-down approach to infer the needed knowledge from the requirements for desired knowledge goals. In the scope of operational information and knowledge management, the focus is on the bottom-up perception for answering the question of how embodied (tacit) knowledge can be transferred to disembodied (explicit) knowledge. However, this is a highly complex two-way or multi-way process that does not take place without incentives. Hence, the task of operational knowledge management includes the creation of framework conditions, which provide the motives and inducements for the production, sharing, and usage of knowledge. North (2011, p.37) emphasises that knowledge is 'the process of expedient interconnection of information'. Thus, the provision, storage, and distribution of information are essential items for knowledge production and transfer.

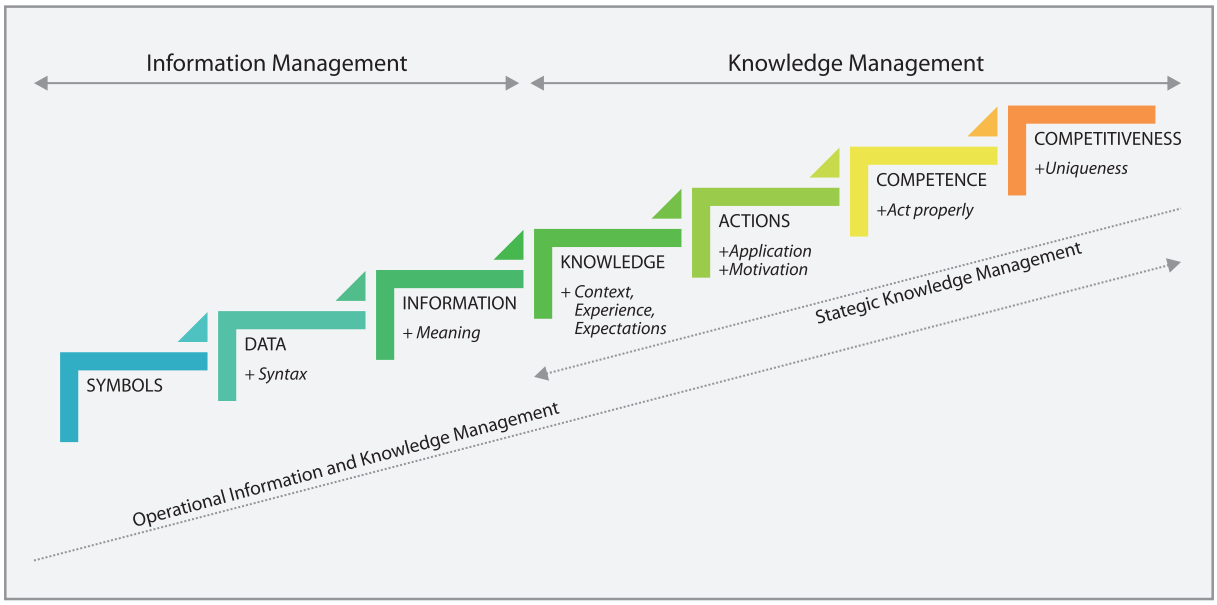

Figure 1: Knowledge Management Ladder
Source: North and Kumta (2014), revised

Inherent in the question of how embodied (tacit) knowledge can be transferred to disembodied (explicit) knowledge are aspects of learning and communication (Hasler Roumois, 2007, p.113). The process of learning can be well described by the SECI model by Nonaka and Takeushi (1995). The SECI model is a dynamic transformation process between explicit and tacit knowledge at different levels: socialisation, externalisation, combination and internalisation. After internalisation, the transformation process restarts from the beginning and the knowledge acquired can be passed back to the socialisation phase, whereby a spiral of knowledge is created. This learning cycle (or learning spiral) can be applied to both individuals and organisations.

The learning cycle model is usually divided into multi-learning levels: single-loop, double-loop, and triple-loop learning. The concepts are mainly based on works by Argyris and Schön (1974). The model can be simplified as outlined below (Pahl-Wostl, 2009): single-loop learning refers to the improvement of actions without changing the guiding values or revisiting the pre-specified strategic objectives of an organisation. Double-loop learning refers to a scrutinising of action goals and organisational guiding values. Argyris (1976) expounded on the concept of double-loop learning in the course of research of decision-making, and proposed the double-loop model as providing feedback and resulting in more effective decision-making. The triple-loop is 'learning to learn', which requires reflecting on single-loop and double-loop learning processes and an analysis of successes and failures. Pahl-Wostl (2009, p.359) outlined that 'the triple-loop learning concept aims at a refinement of the influence of governing variables in terms of governing assumptions and governing values'.

The learning processes must be complemented by actors who manage the processes of learning or knowledge cooperation. This is often a task of moderating (comparable to facilitators and partially mediating actors) (Stuetzer et al., 2013). Moderation implements the 'Cohesion Function' (i.e. to guide group work, to keep the group together, to introduce rules, to oversee, and to harmonise its members) as well as the 'Locomotion Function' (i.e. to set group work in motion and to ensure effective and focused working methods) (Ziegler, 1993). On this basis, the mediating actor fulfils two functions: those of discussion leader and consultant. Another concept of facilitated interaction is that of intermediaries, which is close to the method of moderation. Millar and Choi (2003, p.269) define knowledge intermediaries as organisations that 'facilitate a recipient's measurement of the intangible value of knowledge received'. One function of the knowledge intermediary is to provide firms and/or knowledge producers with a technology and knowledge transfer process in the context of regional innovation systems (Parker and Hine, 2013). The findings about intermediaries provide helpful clues to answer the question about who is responsible for knowledge management.

Regarding the transfer of knowledge, using a unidirectional or one-way transfer from knowledge producers to knowledge consumers (also called 'mode 1') to deal with information and knowledge flows cannot adequately reflect either the challenges of a decision-making process or of a planning support process in a complex, multi-stakeholder environment. This modus of science-policy interaction can be described as the 'science push' and/or the 'demand pull' model (Dilling and Lemos, 2011). The new focus of knowledge transfer activities also considers the communication, translation and mediation of knowledge (Cash et al., 2003). Gibbons et al. (1994) label this focus 'mode 2 knowledge' in the context of transdisciplinary research. The experiences of transdisciplinary research, primarily characterised by the cooperation of scientists and non-academic stakeholders, confirm the barriers and disadvantages of so-called 'mode-1' versus 'mode-2' knowledge production (Hirsch Hadorn et al., 2008). Thus, the assembling of different stakeholders in various groups throughout the whole process of planning is one of the crucial conditions for a sustainable decision-making process and a key pillar of the currently consolidating concept of transdisciplinarity (Gibbons et al., 1994; Pohl, 2011; Opdam et al., 2015). From this point of view, the mutual collaboration of the stakeholders concerned is required in order to support knowledge production, transfer and implementation – this is the idea behind the concept of the co-production of knowledge (Pohl et al., 2010; Enengel et al., 2012). Lemos and Morehouse (2005) argue that an iterative and interactive model for the co-production of science and policy requires interdisciplinarity, stakeholder participation, and the production of usable knowledge, which can be incorporated into all stakeholders' decision-making processes. They also acknowledge in this frame that usable knowledge 'not only must be tailored to fit stakeholders' needs and uses, but must also be made accessible to those users' (Lemos and Morehouse, 2005, p.62).

The concept of 'communities of practice' (CoP) is tailor-made for the complex challenges of integrative information and knowledge management, and gives answers to the question of what an adequate 'space' for organising knowledge management and co-production of knowledge is. CoPs are social structures that focus on knowledge and enable the management of knowledge to be placed in the hands of knowledge adopters (Wenger, 2004). The co-production of knowledge through collaborative learning between knowledge producers and adopters within CoPs is a more suitable approach for the implementation of knowledge systems than mere knowledge transfer (Roux et al., 2006; Rydin, Amjad, and Whitaker, 2007). The self-organising nature and the typically informal character of CoPs contribute to overcoming the lack of mutual engagement in two-way communication and the strategy-of-hope of knowledge transfer in push-pull strategies (Roux et al., 2006). Wenger (2004, p.3) describes the self-organising nature of CoP as being that practitioners 'need to be in dialogue with executives in the organisation, other CoP, and experts outside the organisation'. A web-based CoP can be

described as a suitable modern knowledge management tool, and needs the commitment of intermediaries in order to control or govern the knowledge transfer and transfer channels in a multi-stakeholder environment. This tool-based approach answers research question 1.

2.2. Managing Knowledge – The Meaning of Planning Support Systems (PSS)

PSS represent an instrument for organising different knowledge sources, rationalities, scales and channels. According to Klostermann (1997, p.51), 'PSS … should be designed to provide interactive, integrative and participatory procedures for dealing with non-routine, poorly structured decisions'. Furthermore, he stresses that PSS 'must also pay particular attention to long-range problems and strategic issues and explicitly facilitate group interaction and discussion' (Klostermann, 1997, p.51). A distinction is thereby made between PSS and Decision Support Systems (DSS) and Spatial Decision Support Systems (SDSS), as the latter 'are generally designed to support shorter-term policy making by isolated individuals and organizations' (Klostermann, 1997, p.51).

Up until now, approaches to PSS which place knowledge as a resource at the focus of their attention are still in their infancy. The significance of knowledge as a resource has been increasing, along with the significance of participation in planning processes since the 1990s (in the sense of planning for citizens in order to plan with citizens). Even if the handling of knowledge has been part of the discussion in spatial sciences for quite a long time (as well as concepts of the knowledge society, knowledge regions, and learning regions), the management of complex stocks of knowledge is still challenging (Klostermann, 1997; Geertman, 2006). In the literature, various possibilities are presented for a system of knowledge management in, or rather for the benefit of, spatial planning.

Te Brömmelstroet and Bertolini (2008) have developed an approach to establishing a constructive and structured dialogue between modelling from the field of traffic planning on the one hand, and from spatial planning on the other, in order to make integrated planning possible at an early stage in the form of Mediated Planning Support. They highlight essential differences between the two groups of actors and emphasise the necessity of mutual learning processes, particularly with a view to the handling of tacit knowledge. Evers and Hofmeister (2010) have presented a participatory Planning Support System (pPSS) in the context of local site management. They define pPSS as a system to include local and narrative knowledge (Evers and Hofmeister, 2010, p.43). In contrast to information systems, a pPSS integrates exchanges, online discussions and online decision-making (Evers and Hofmeister, 2010, p.43). Rubenstein-Montano (2000, p.163) presents a methodical approach towards integrating Urban Information Systems more strongly into urban knowledge management: 'knowledge management encompasses much more than technologies for facilitating knowledge sharing' and emphasises the inclusion of cultural aspects and of tacit knowledge. Rinner, Keßler and Andrulis (2008, p.36) 'present an online map-based discussion forum that enables internet users to submit place-based comments and respond to contributions from other participants'. The internet is thereby regarded as an efficient tool for two-way communication in order both to support the discussion of spatial decision-making processes, and to participate in the shaping of the decision itself.

The approaches outlined here show the significance of knowledge and its management, but each embeds it in a rather narrow context of specific spatial challenges. As such, a pPSS inserts stakeholders into a specific time slot and confronts them with a specific question in order to receive additional information and positions during a particular planning step. This can accelerate the acceptance of planning decisions. The planning and decision process remains the responsibility of the operational institution. In contrast to that selective participation, the transdisciplinary approach integrates stakeholders throughout the entire planning process – from problem definition, through the development of solutions, and up to their implementation. This ensures the co-production of knowledge throughout all phases of the process. Nevertheless, current systems of pPSS constitute important aspects for transdisciplinary planning and decision processes.

At the same time, Vonk (2006, p.38) points out the fact that 'the ability of PSS to support communication between citizens, professional stakeholders and planners remains largely underused'. Up to now, PSS have dominated planning practice, especially as tools in project management and spatially-related information

systems (geographical information systems, GIS). GIS, in turn, is an essential component of PSS (Geertman and Stillwell, 2004, p.293) and are often, in cooperation with scientific facilities, complemented and validated by models (simulations, scenarios, etc.) (Celino and Concilio, 2010). Thus, the comprehensive PSS described above are not fully implemented in practice as yet (Vonk, Geertman and Schot, 2005; Geertman, 2006; te Brömmelstroet, 2013). This is attributed to various obstacles. Vonk, Geertman and Schot (2005, p.916) have come to the conclusion that the deployment of PSS in planning practice is first and foremost dependent upon previous experience in planning practice, the user-friendliness of the systems and the user's awareness of the potential of PSS. They further emphasise that both the quality of the data and its availability are important influential factors in planning practice that decisively determine the effective deployment of PSS. Geertman (2006, p.865) summarises the major obstacles as follows: PSS are

> too generic, complex, inflexible, incompatible with the wicked nature of most planning tasks oriented towards technology rather than problems, incompatible with the less formal and unstructured information needs and too focused on strict rationality.

Te Brömmelstroet (2013, p.306) also points to the fact that only a few PSS have been evaluated. The satisfaction of those actors who had been involved in the development of the PSS or were intended to use the PSS is also largely under-evaluated (te Brömmelstroet, 2013, p.304; also Laurian and Shaw, 2008; Faehnle and Tyrväinen, 2013).

To conclude, spatial planning, as an intermediary, needs feasible structures for managing different knowledge stocks and, thus, complexity in land use. PSS constitute one suitable instrument to cope with uncertainties, multi-actor-environments and conflicting land use demands by offering planners and decision makers opportunities to test scenarios on spatial development and discuss potential interventions. At this point, hardware and software of PSS have been sufficiently developed to meet even the requirements of participative approaches. Nevertheless, resilient responses to real-world problems are rare (te Brömmelstroet, 2012). In particular, gaps in PSS exist regarding the function of communication and knowledge management (Vonk, 2006). In consequence, further developments are desirable from both a scientific and user-oriented point of view, handling complex knowledge bases in order to address comprehensive questions of sustainable land use and spatial development.

3. A Prototype for Knowledge Platforms: An ICT-based Approach

Taking into account Davoudi's (2015) concept, 'planning as practice of knowing', grasping the knowledge-action relationship, this section describes the development of a framework and the implementation of a knowledge platform that is labelled as a 'knowledge library'. The platform provides users with opportunities for efficient information and knowledge brokering, sharing, and transfer within a transdisciplinary environment for the linking of knowledge with action.

The findings about knowledge management frameworks in the context of land use and spatial planning in Section 2 serve as a guideline for a conceptual design of an integrated knowledge management system considering aspects of transdisciplinarity. Figure 2 shows a simplified framework for a knowledge management system organised within a CoP.

The conceptual design elaborated below includes knowledge suppliers and adopters, the three modes of science-policy interaction (henceforth referred to as modes of transfer), and the mutual learning process. The first mode of transfer is analogous to the 'loading dock' approach by Cash, Borck and Patt (2006b), where knowledge suppliers set the knowledge agenda often without regard for users' needs (science-push strategy). In the second mode of transfer, new knowledge is set by those making decisions outside the scientific community (demand-pull strategy; Dilling and Lemos, 2011). In contrast, in the third transfer modus (co-production of knowledge), both parties adopt the understandings of producer and user, and link knowledge. Intermediaries take up the function of governing or co-governing, as well as facilitating knowledge flows, and they help to bridge the knowledge-action gap between producers and users (Millar and Choi, 2003). Therefore,

the fusion of the three modes of transfer and the multi-level organisational learning cycle inside the CoP is desirable. This is a sequential approach where the intermediaries:

- link the knowledge of suppliers and adopters,
- analyse their appropriate knowledge transfer strategy in the context of their disciplines (push and pull strategy), and
- adjust the organisational learning cycles for the agreement of common action goals.

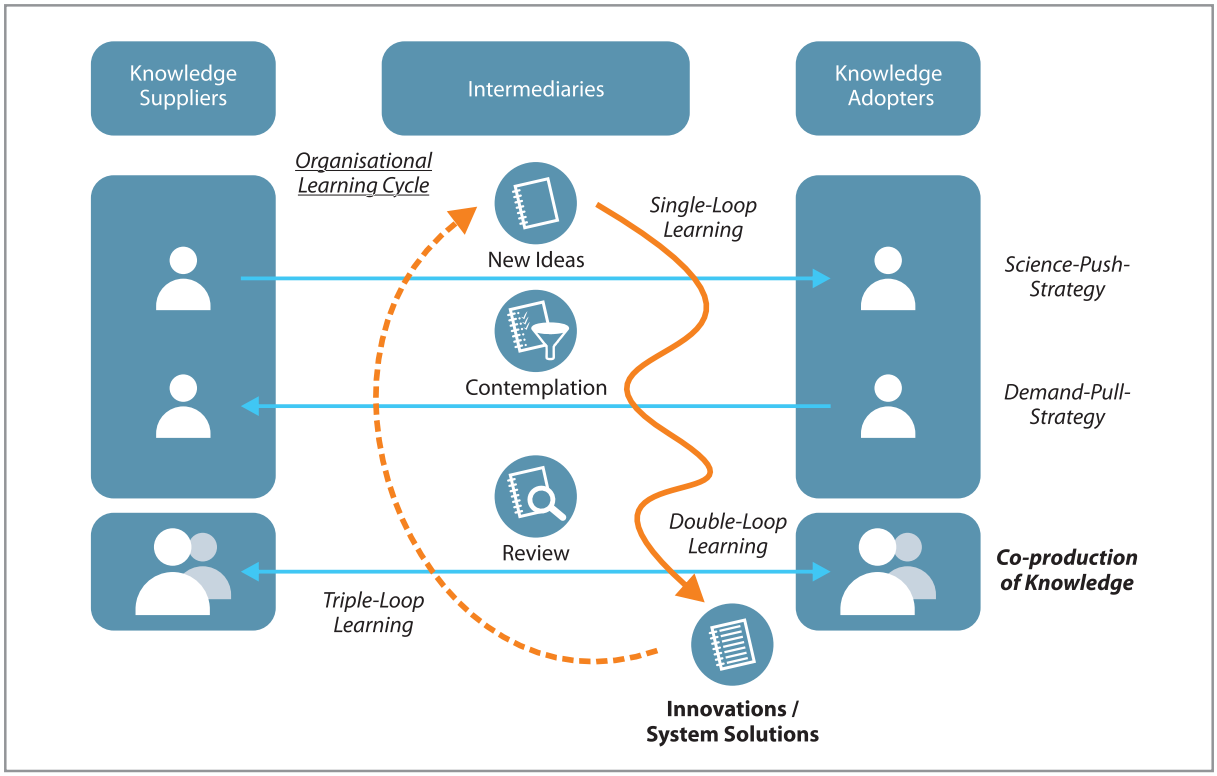

Figure 2: Knowledge Management Framework for a Community of Practice (CoP).
Source: the authors.

At the first stage, the task of single-loop learning is to bring stakeholders together on a common level by analysing the supply and demand of innovations or system solutions. On this basis, new ideas are developed or already existing ideas are reframed. The contemplation of mutually developed (new) ideas proceeds to a comprehensive review of common action goals at the third stage. This is a double-loop process and requires the mutual co-production that a CoP provides. A triple-loop approach is necessary if unsatisfactory agreements on common action goals arise. This conceptual framework answers research question 2.

Table 1 gives a summary of the sequential approach of knowledge management for enhancing decision-making capacity in a spatial planning context.

This section illustrates the practical implementation of the concept outlined above. Integrated information and knowledge management driven by a CoP is the basic idea for the implementation of this internet-based platform. The knowledge platform is deliberately titled the 'knowledge library' so that the users already associate the platform with information and knowledge storage. A special feature of the knowledge library is its bilingual design – in German and English. Here, the knowledge library functions as the data, information and knowledge broker for sustainable land management. The disembodied, explicit knowledge is the major type of knowledge for brokering through the knowledge platform. However, a conversation about selected knowledge library contents within a CoP can facilitate the transfer of tacit knowledge to explicit knowledge, particularly by using the integrated online discussion board called the Forum. The Forum is an interactive user interface (Web 2.0 tool) that offers knowledge suppliers and adopters in transdisciplinary research projects the opportunity to perform the indexing of knowledge products jointly in order to increase visibility for the target group and to strengthen transfer and implementation. This is the chief added value of a knowledge library in handling complex multi-stakeholder communities.

Table 1: Sequential Approach of Knowledge Management for Enhancing Decision-making Capacity in a Spatial Planning Context

Approach	Modes of transfer	Knowledge pathway[1]	The key role of intermediaries	Knowledge transfer
Single-loop-learning	Science-push-strategy	S ⇒ I ⇒ A	Facilitating of learning process and group interaction	Transfer of (new) spatial planning frames from scientists to planners and decision makers; [2]based on data and information
Single-loop-learning	Demand-pull-strategy	A ⇒ I ⇒ S	Facilitating of learning process and group interaction	Transfer of (new) spatial planning concepts from decision makers and planners to scientists; [2]based on data and information
Double-loop-learning	Co-production of knowledge	S ⇔ I ⇔ A	Arrangement of mutual planning action aims	Collaborative knowledge production by contemplating planning action aims and problem framing - first outcomes are possible; [2]applied (new) co-produced knowledge in frame of planning action goals by further development of competence
Additional approach for complexity processes in a planning community:				
Triple-loop-learning	Co-production of knowledge	S ⇔ I ⇔ A	Collaborative reframing of the structural system by an iterative approach (paradigm shift)	Readjustment of the regional system of spatial planning aims (e.g. change in spatial planning's regulatory frameworks); [2]development of competitiveness
Organisational learning cycle	Co-production of knowledge	A ⇔ (I) ⇔ S	Establishing of self-organising structures	Qualify the CoP in mutual co-production of tacit to explicit knowledge for improved outcomes related to spatial planning aims; [2]establishing knowledge-based competitiveness

Source: the authors
[1] S = Knowledge suppliers | I = Intermediaries | A = Knowledge adopters
[2] Relationship to the knowledge management concept in Figure 1

User access to the information and knowledge stocks runs via five category-based paths. These paths are categorised by five main groups: products, audience, subjects, regions, and projects. Figure 3 is a screenshot showing the landing page for the knowledge library. On the left side, everyday navigation of the website is represented. In the middle field, the heading is at the top and a customised full-text search engine to the entire database of the knowledge library is provided at the bottom. Above the heading, a category-based search engine especially developed for the library enables more focused access to the collected data. In between, a short introduction manual describing the function and the applications of the knowledge library is displayed.

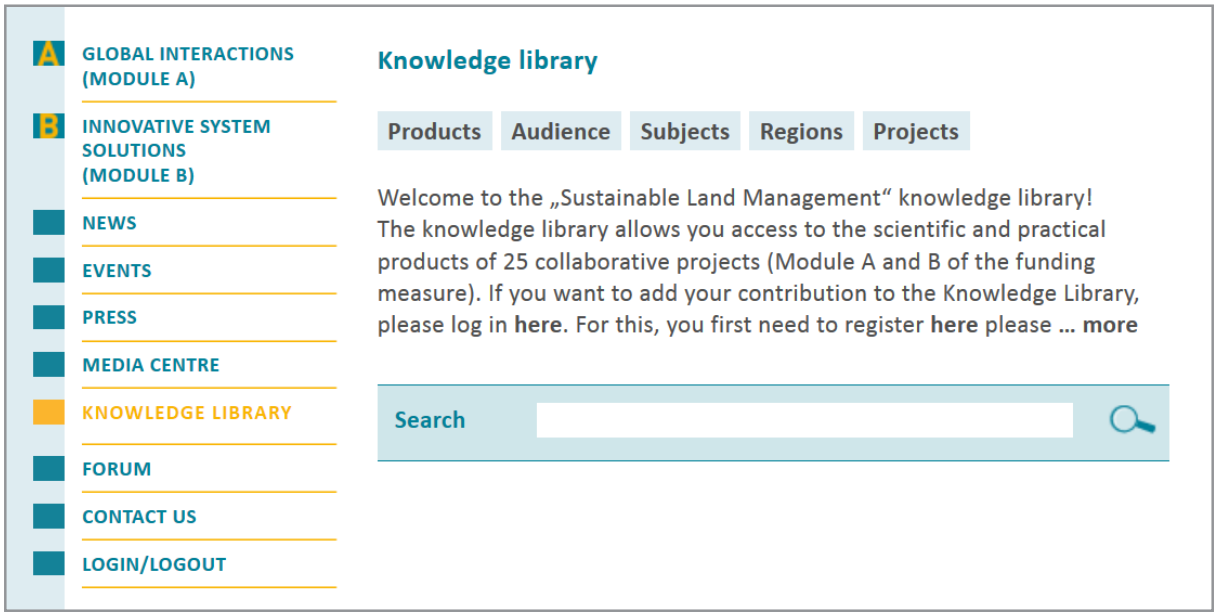

Figure 3: The Knowledge Library of 'Sustainable Land Management'
Source: the authors (available on: http://nachhaltiges-landmanagement.de/en/library/documents/)

One of the key challenges in dealing with internet-based knowledge platforms concerns the visibility of information and knowledge stocks. In order to optimise this process, a category-based approach was chosen, supplemental to the conventional search mechanism. In addition, each category is specified by category-specific keywords. In the best case, the indexing of each dissemination product (i.e. an article, video, image, or hyperlink) is made by the knowledge suppliers themselves. However, with a multi-stakeholder community, ambiguousness of terms often leads to multiple mentions of keywords. Therefore, the role of intermediaries is crucial in the mutual indexing process.

To increase the acceptance of both categories and keywords, we employed a 'social tagging' method, in which 'priority users' select the categories and keywords themselves. Priority users were those who participated in research projects (scientists and practitioners) involved in the funding programme 'Sustainable Land Management'. Social tagging is a method of indexing documents with content descriptive data that enables suppliers to index their documents themselves, which is also called folksonomy. Folksonomies have become a new type of knowledge organisation system (Weller, 2010, p.70). In the case of the knowledge library, the method of social tagging was applied in an adapted form by creating categories with corresponding keywords (the indexing process). Utilising selected participants of research projects and the intermediaries of the funding programme (Weith et al., 2010) helps the mutual indexing process by facilitating the accessibility of knowledge demands and revealing users' tangential interests. The process of social tagging promotes a strategy of linking knowledge with action by overcoming the lack of mutual understanding of synonymously used content-descriptive data. Folksonomies, or specifically the social tagging method, partly answered research question 3.

Usage of the knowledge library is explicitly not reserved to registered users only. However, only registered users are authorised to upload dissemination products to the knowledge library (i.e. articles, videos, images, or hyperlinks) in order to show their results. As members upload their dissemination product, the system asks them to tag their uploaded product with default tags. This means users' access to the knowledge library will be crucially supported by categorised keywords (tags).

Table 2 summarises suitable and applied problem-solving approaches for the explicit challenges of PSS. In the left column, the main challenges of PSS are shown, whereas the right column contains options about how to cope with current challenges of PSS. For enhanced decision-making capacity, these problem-solving approaches meet current demands in planning research, as 'the collaborative process should contribute to interrelate concerns of different actors and nurture their capacity to mobilize specific networks to contribute to sustainability' (Faehnle and Tyrväinen, 2013).

Table 2: Applied ICT-Based Problem-Solving Approaches for Enhanced PSS

Challenges of PSS	Applied Problem-Solving Approaches
… should be designed to provide interactive, integrative and participatory procedures for dealing with non-routine, poorly structured decisions (Klostermann, 1997)	The Co-production of Knowledge via the Knowledge Platform (Knowledge Library and Forum)
… must also pay particular attention to long-range problems and strategic issues and explicitly facilitate group interaction and discussion (Clarke, 1990; cited in Geertman and Stillwell, 2004)	The Community of Practice (CoP) within the Knowledge Platform
… are generally designed to support shorter-term policy-making by isolated individuals and organisations (Clarke, 1990; cited in Geertman and Stillwell, 2004)	Open Access to the Knowledge Library and the Forum
… transfer embodied tacit knowledge into disembodied explicit knowledge	The Organisational Learning Cycle (double- and/or triple-loop learning) within the CoP of the Knowledge Library and the Forum
… manage and facilitate the process of mutual learning and knowledge cooperation	The Intermediaries of the Knowledge Platform

Source: the authors

4. Rating the Prototype: Strengths and Options for Further Development

The concept of the ICT-based knowledge platform meets the need for integrated information and knowledge management as well as the challenges of PSS. In particular, the platform includes problem-solving approaches that have already been applied (see Table 2). This is the strength of the platform. In detail, the knowledge platform contributes to:

- mutual planning agenda-setting in complex multi-stakeholder environments (see Table 1),
- bridging the knowledge-action gap between science and practice,
- the initiation of learning cycles for facilitated transferring of embodied into disembodied knowledge (transdisciplinary approach and grasp) and for improving consensus,
- the contemplation of and reflection on existing knowledge as well as the reframing of normative or pre-normative values,
- purposeful and effective dialogue processes,
- adequate stakeholder participation, and
- potential utilisation of metadata by intermediaries and users themselves.

In addition, the knowledge platform concept seems to be an appropriate model for a co-produced PPGIS (Public Participation Geographic Information Systems; Sieber, 2006). According to generally accepted definitions of PSS which call for GIS components, the platform might be not promoted as a PSS in the conventional sense. However, in a broader understanding, the platform can be seen as a reframed PSS, providing not only information but knowledge. The experiences of developing and implementing the platform are especially worthwhile for further developments of PSS, in particular to fill the gaps regarding communication and knowledge management functions. The platform provides basic structures for mutual learning, enhances decision support capacity and, finally, strengthens robust decisions that will gain considerable acceptance in politics and society. Notably, it contributes to dealing with the complexities and irrationalities of social reality (Salet, 2014, p.295) by allowing uncertainties to be discussed in the Forum.

Salet (2014, p.298) defines five dimensions to verify the provision of 'authentic' spatial planning knowledge. We use them for a preliminary assessment of the developed platform. Salet refers to the 'normative sense of spatial direction', 'normative dimension of knowledge', 'dimension of action', 'dimension of existing practices', and 'dimension of emergent practices'. Taking these five dimensions as benchmarks helps to understand and evaluate the platform against the requirements of planning practices, taking the current development status of the platform into account. The platform addresses the first and second dimension by integrating the different products and positions of all actors that are interested in the topic. The Forum offers the possibility not only to foster scientific knowledge exchange, but also exchange between practitioners, and between scientists and practitioners. In this way, multi-knowledge management is stimulated. By tagging the products and using the category-based search engine, normative ideas about space-specific developments can be found and users can exchange these ideas via the Forum. The other dimensions reveal the limitations of the platform. This is caused by the fact that the platform has indeed been implemented, but experiences about user behaviour in the long run are missing at this point. Nevertheless, the platform is designed as a tool to manage knowledge that is relevant for upcoming action. However, the organisation of future activities is not the main objective of the platform (although it can be further developed and used in this way). Currently, we actively promote the platform in a multi-stakeholder environment to raise awareness about the possibilities of the knowledge platform and to motivate users to cooperate during the process.

In the future, we anticipate further challenges regarding the evaluation of (real-world) outcomes supported by the knowledge platform. The evaluation process is not a single task for knowledge adopters or intermediaries, but rather a mutual process in a frame of references analogous to the triple-loop approach. Moreover, one weakness of the platform might be the facilitation of long-term continuation of dialogue processes and stakeholder participation, which is strongly linked with the funding period (lack of personnel and financial resources).

Finally, from our point of view, the platform as it has been designed and implemented provides theoretical and practical solutions how to cope with the challenge to interlink PSS and knowledge management much better. The co-production of knowledge fostered by a CoP fills the communication gaps by paying more attention to the dimensions of novelty and cohesion (te Brömmelstroet, 2013, p.305). Further, the implementation of the knowledge library within a CoP meets the demand of Geertman (2015, p.329), who calls for integrated communities of PSS research and practice 'in which the instrumental development and planning application of PSS will be driven by developers and potential users in an interactive, incremental and iterative process'. Moreover, the management approach tackles the lack of systematic approaches and improves planning processes, especially regarding the challenges of visibility (by the open access characteristic) and consensus (by the organisational learning cycle). The integrated character of a CoP is an added value for PSS and contributes

to answering research question 4. However, more empirical results about user behaviour and user demand are necessary to assess practical use.

5. Lessons Learnt: Conclusion and Outlook

The usefulness of PSS is given by improving the effectiveness and efficiency of planning processes and planning outcomes. Scientific studies nonetheless reveal that, despite well-engineered hardware and software, there are still many obstacles in implementing PSS in planning practice. In the current practice of sustainable land management, DSS or GIS are primarily used in order to analyse sectoral questions and to provide information for planning practice. The development of learning systems and the differentiated management of knowledge have only played a minor role so far. Above all, this can be traced back to the fact that knowledge is often simplistically equated with information and communication to third parties realised by one-way implementation and transfer. Despite the claim of transdisciplinary research, the theoretical-conceptual confrontation with (tacit and explicit) knowledge and the management thereof is often poor.

In consequence, the concept for an integrated ICT-based knowledge platform presented above reflects the possibilities for improving the effectiveness and efficiency of planning processes and planning outcomes in combination with a PSS. Thus, the paper merges discourses about sustainability research and knowledge management, developing more robust solutions for sustainable land use.

The chief function of the knowledge platform ('knowledge library'), which is already developed and in use, is to bridge communication gaps in planning practices, taking a multi-stakeholder environment into consideration. This occurs by supporting knowledge co-production within a CoP. The overall goal is linking knowledge with action to co-produce robust solutions for promoting sustainable land use and reducing land use conflicts by:

- bringing together scientists, practitioners and public stakeholders, working on real-world problems,
- addressing core activities in knowledge management,
- dealing with complexity,
- initiating learning cycles, and
- co-governing (public) participation processes.

In Germany, spatial planning authorities at regional level might be appropriate intermediary units for using such a platform to coordinate different knowledge stocks and to co-produce knowledge for robust land use solutions – this in respect to communicative and collaborative planning. Moreover, we illustrate options for the further development of PSS in order to advance its implementation. Although the knowledge platform presented in this paper has been implemented, long-term experiences with its application are still inconclusive. Due to the prototypical character of the platform the results are not yet exhaustive.

The platform we have developed constitutes an approach that particularly meets the complex requirements of sustainable land management, going beyond existing approaches to spatial planning and its competences. The platform offers a methodical framework of how to handle complexity in an environment of trans-sectoral target settings. Thus, it serves as a blueprint for collecting, bundling, explaining, and providing knowledge that is sometimes extremely heterogeneous. It also proves to be an adequate tool to enhance learning processes. Spatial planning, or those institutions entrusted with spatial development, could take up a moderation function to balance various land use demands, using the platform as an intermediary instrument. Beyond that, it also might be a promising approach for innovative landscape conflict management, negotiating the demands of various stakeholders. Nevertheless, the methodological improvements of knowledge management tools require reliable evaluations of the tools themselves regarding the applicability as well as the outputs and outcomes. This is a task for the future, as it is for all other improvements in PSS systems.

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