STAKEHOLDERS' PERCEPTION OF THE RELEVANCE OF WATER AND SEDIMENT CONNECTIVITY IN WATER AND LAND MANAGEMENT

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Short title:

STAKEHOLDERS' PERCEPTION OF WATER AND SEDIMENT CONNECTIVITY

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Abstract

Using concepts of connectivity in challenges regarding land and water management (flooding, erosion, nutrient leaching, landslides) can only be fully harnessed if knowledge is communicated well between scientists and stakeholders. Proper communication requires prior understanding of end-users' perception of connectivity as a useful framework. Therefore, we analysed (i) perceptions of ‘connectivity’ for stakeholders involved in water and land management across Europe, (ii) potential for stakeholders to apply connectivity-related measures in their management decisions, (iii) stakeholders’ biggest challenges in water and land management, and (iv) stakeholders' expectations for future ‘connectivity’ research agendas. We studied 85 questionnaires from 19 countries using a grounded theory approach. One-third of stakeholders understood connectivity in its scientific context, while 39% perceived connectivity indirectly through their personal experiences (e.g., water and sediment fluxes and erosion). Half of stakeholders’ perceived links and challenges were related to availability of data and methods, communication, and institutions or policy, while others believed they were related to water quality and quantity, soil erosion and quality, and climate change. Half of the stakeholders considered connectivity management important, and one-third showed high interest in managing connectivity. Adopting connectivity into management is hindered by institutional- and policy-based management limitations, insufficient data and methods, and ineffective knowledge transfer. Explicitly considering heterogeneity of stakeholder perceptions is required for projects regarding management of connectivity at European, national and local scales.

Key words: stakeholders, water and sediment connectivity, perception, management potential, knowledge transfer

Introduction

Research on water and sediment connectivity (furthermore- connectivity, unless noted otherwise) has received increased attention across the fields within geosciences (Bracken et al., 2015; Chartin et al., 2016; Laudon et al., 2016; Masselink et al., 2016a, 2016b; Souza et al., 2016; Welter & Fisher, 2016; Lane et al., 2017). Water and sediment connectivity is currently defined as 'the degree to which a system facilitates the movement of matter and energy through itself; it is thought to be an emergent property of the system state' (Connecteur WG Theory, 2016). Aside from academic/scientific applications of connectivity concepts, researchers have acknowledged that connectivity concepts and methods have potential to supply vital tools to stakeholders outside academia (furthermore -stakeholders) for tackling challenges in land and water management such as flooding, nutrient and contaminant leaching, reservoir sedimentation, habitat fragmentation, land degradation or landslide development (e.g., Gay et al., 2016; Mekonnen et al., 2016; Tiranti et al. 2016, Vigiak et al., 2016; Poeppl et al., 2017). European scientists are aiming to transfer contemporary connectivity tools to applied sciences and stakeholders working in water and land management (Connecteur WG Society, 2016). Despite numerous studies using stakeholder analysis to investigate stakeholders' perceptions of water and land management, conflict negotiations and participatory environmental management and policy (e.g., Grimble & Chan, 1995; Reeds et al., 2009; Lestrelin et al., 2012; Sjögersten et al., 2013; Tripathi et al., 2014; Steinhäußer et al., 2015; Bouma & Montarella, 2016; Nigussie et al., 2016, Shikangalah et al., 2016; Subirós et al., 2016), it remains unclear how connectivity is integrated in stakeholders' understanding of water and land management across Europe. Furthermore, little is known on how connectivity and recently developed connectivity tools (including highly specialised methods for connectivity measurement approaches, connectivity modelling and indices of connectivity) are applied to management challenges by stakeholders. Differences in perceptions of an observable phenomena (e.g., connectivity, health, policy adoption, land degradation, flooding) play an important role in interpreting that phenomenon and the attitude that is adopted towards it (e.g., Abbott et al., 2006; Herzfeld & Jongeneel, 2012; Tripathi et al., 2014; Assefa & Bork, 2015), and together with inadequate knowledge transfer may complicate even the best management practices for tackling environmental problems (Fazey et al., 2013; Prager & Curfs, 2016). Therefore, for successful knowledge and technology transfer of connectivity concepts and tools in Europe, it is of particular importance to first determine differences in perceptions of connectivity, especially as they relate to perception in conditions of existing environmental, cultural, historical, societal and institutional diversity, where stakeholders are to a certain extent tied by common EU legislation (e.g., Water Framework Directive, Common Agricultural Policy). Therefore, the objectives of this study are (i) to analyse perceptions of 'connectivity' for stakeholders involved in water and land management across Europe, (ii) to evaluate stakeholder's potential to apply connectivity related measures in their management decisions, (iii) to discuss the biggest challenges in water and land management, and (iv) to summarize stakeholders' expectations of the current connectivity research agenda.

Methods

This research is embedded in the European Union (EU) COST Action ES 1306 Connecteur project (furthermore Connecteur), representing a network of researchers and practitioners from EU and associated countries working on connectivity. This group of collaborators was used to help define data collection set-up and methods described below, which apply a network approach to qualitative stakeholder analysis.

Questionnaires

The perceptions (i.e., the ideas and notions of a topic that someone has awareness of) of academics (furthermore; scientists) and stakeholders greatly differ on a range of environmental issues (Prager & Curfs, 2016). Thus it was expected that stakeholders are unfamiliar with connectivity concepts in contemporary research. In order to formulate questions investigating stakeholders' perceptions, two hypotheses were followed.

Hypothesis 1: Stakeholders primarily have perceptions of connectivity based on empirical experiences and only in relation to their own challenges. Empirical experience is hereby understood as accumulated knowledge or skills derived from observation through participation in life events or activities.

The majority of 46 scientists polled at the 2nd MC Meeting of Connecteur (16-17/09/2015, Durham, UK) expected that stakeholders to have intuitive knowledge on connectivity, confirming the credibility of this hypothesis (Figure 1). The hypothesis (partially) represents one mental model held by European connectivity scientists on stakeholders' perceptions of connectivity issues and relates to the first objective of the study. The questioned scientists also presumed that a minor number of stakeholders were aware of current connectivity research and hardly any would actively apply connectivity tools in their daily work.

Similarly, we expected that:

Hypothesis 2: Despite stakeholders being unaware of recent connectivity research developments, they have potential to manage water and sediment connectivity based on their indirect perception of connectivity and current management of connectivity related issues.

Indirect perception is understood as experience-based intuitive insight on connectivity without knowledge of the scientific definition and concept of connectivity (which define direct perception). This hypothesis addresses the second objective of the study. The third and fourth objectives were addressed using descriptive statistics, and the remaining objectives were addressed by analysis of questionnaires.

A questionnaire of 20 questions, written in English, was developed for stakeholders, and included free-response questions, closed- and multiple-choice questions (Table 1). Questions were based on an interdisciplinary participatory discussion from a workshop of Connecteur (Connecteur Society, 2016) in Berlin, April, 2015. The questions supporting respondents' intuitive understanding and spontaneous definition of connectivity were preferred over questions that may have required pre-existing scientific awareness of connectivity or interviewers' perceptions. The questions included (i) general statistics about the respondents; (ii) their responsibilities and spatial range of influence, (iii) the type of data they collect and/or use, (iv) people and organisations they cooperate with, (v) the biggest challenges of their work in current water and land management, (vi) their understanding of connectivity and its importance in management, (vii) expectations of connectivity science/scientists. Prior to the interview, respondents were informed about the anonymity, and purpose of the interview, according to ethical regulations (developed by TU Berlin, Germany).

Questionnaires were translated into 14 languages (Dutch, Estonian, Finnish, French, German, Hungarian, Italian, Maltese, Polish, Portuguese, Serbian, Slovak, Spanish and Turkish) by volunteer scientists from Connecteur.

Survey approach and stakeholder sampling

Any number of volunteering scientists from Connecteur were permitted to contribute to the research by interviewing as many stakeholders as they chose. Thus, the number of participating countries and total interviews performed were semi-random, but limited to the countries within the COST network. Less than half of 29 interviewers had previous experience conducting semi-structured interviews, and 66% had previous experience with stakeholders. Additional information on interviewers' backgrounds in the use of applied methods and cooperating with stakeholders is found in Data S1.

A mixed-sampling approach combining the criterion- and snowball-sampling methods (Patton, 2002) was employed in order to include relevant stakeholders. Interviewers sampled stakeholders within their own professional network and institutions (Table 2) while excluded those stakeholders having direct working relationships with scientists working on connectivity topics. We provided interviewers with guidelines for the interview format, questions to ask, and the important components to be extracted from the questionnaires. Questionnaires were performed in person or via phone or email, depending the individual stakeholder's preference and options available to the interviewer. Because recording equipment was unavailable, we used both transcribed and summarized interviews that were translated to English by the interviewers.

Dataset

A total of 85 stakeholder questionnaires were implemented by 29 different interviewers from 19 European countries (46% stakeholders from Spain, 11% from Bosnia and Herzegovina, with the remaining 43% from other countries, Table 3). Most commonly respondent were males having tertiary education or PhDs, and with an average of 18 years working experience. Respondents were mainly administrators (44%) and farmers (38%). A description of the dataset compiled from questionnaires is available in Table 3. Stakeholders answered from 93 to 100% of 20 total questions. For questions 8, 14 and 15 (Table 1), 11-15% of stakeholders did not provide a response.

Data evaluation

Data was evaluated using grounded theory, an inductive technique for interpreting recorded data about a social phenomenon (Glaser & Strauss, 1967), applying the coding approach described in Strauss & Corbin (1990, 1998) as follows. Coding involves classifying and categorizing text data segments into a set of (i) codes, (ii) categories, and (iii) relationships. Firstly, an open coding procedure identified key ideas and perceptions hidden within the text data. A code representing the basic concept of a portion of a text was assigned to it. Each individual code originated from the text, using respondents' or researcher wording to define the code definitions. This process was continuous and the number of codes increased with the portion of analysed text. Secondly, similar codes were categorized to represent specific and meaningful concepts. Open coding, categorization, and axial coding were performed simultaneously. Axial coding targeted the analysis of relationships between concepts and constructs. The selective coding procedure prioritized categories, enabling identification of categories relevant to the research questions, and the ability to link them to the remaining categories. Identified codes, categories and relationships were further analysed by mixed quantitative and qualitative approach consisting of (i) frequency statistics of categories, (ii) story lining (using concepts and constructs to refine outlined stories), and (iii) visualising the relationships.

Analysis of stakeholders' perception

In order to test the first hypothesis, we assumed that stakeholders' definition of water and sediment connectivity (Table 1, question 16) referred to their direct perception of connectivity. Furthermore, we suggest that links in a landscape described by stakeholders (Table 1, question 13) provide insight to how stakeholders perceive landscape functionality, as well as accumulated indirect knowledge of water and sediment connectivity. Described links were proof of indirect observations or knowledge of water and sediment connectivity. The codes describing the identified links were ranked- in relation to connectivity- as "well linked", "partially linked" or "not linked". "Well linked" descriptions were those acknowledging the existence of fluxes and linkages between landscape compartments, and/or their spatial and temporal variability. "Partially linked" descriptions included those that mentioned landscape units without a specific type of link, described management effects on natural systems, or used phrases such as "everything is connected". The last category, 'not linked', contained answers such as "no, none, and/or not relevant", or when no response was provided. Stakeholders' perception was further analysed in the context of the main challenges described below.

An index for measuring Connectivity Management Potential

In order to test the second hypothesis, an index of connectivity management potential (*CMP*) was proposed as follows

$$CMP = RL \times IML \times AML + RC \quad \text{(eq.1)},$$

where: *RL* is recognising linkages related to connectivity (based on answers to question 13 in Table 1), *IML* is recognising the importance of connectivity related linkages in management (Table 1, question 14), *AML* is actually practicing management of connectivity related linkages (Table 1, question 15), and *RC* is recognising the role of connectivity in management (Table 1, question 17).

CMP reflected the influence of perceived value *(IML)* and knowledge (*RL*) for adoption of environmental management decisions (e.g., Greiner & Greg, 2010; Kragt et al., 2017). The *IML* was presumed to be more relevant for *CMP* than *RL* and *AML (AML < RL < IML*), and *IML* and *RL* limiting for *CMP*. *RC*- linked to direct perception of connectivity*,* was expected, but not 100%, to have additional benefits to *CMP*, and was therefore expressed by addition' rather than multiplication.

Evaluation of stakeholders' answers to questions 13-15 and 17 (Table 1) is described in the "*Data evaluation" section*. First, we evaluated the ability to contextualize meanings of the variables (i.e., RL, IML, AML, and RC) using abbreviated 'coded' phrase. Descriptive categories were assigned with quantitative values in order to express the agreement between the variables and the final coded phrase. Categories assigned to each variable included 'well linked' (> 50% agreement), 'partially linked' (25-50% agreement), and 'no link' (0-25% agreement). Subsequently, a unique numerical weight was assigned to each variable and category of codes in order to obtain unique *CMP* values. The weights were chosen in order to represent the ranking according to the relevance to *CMP (RC < AML < RL < IML*). Weights were chosen in order to obtain unique *CMP* values by different combination of variable and category, except for *IML* and *RL* were not linked. Unique values of CMP were produced solely for ranking purposes and demonstrating differences between stakeholders' groups. The code's ranking ranged from: highest for "well linked" (*RL*-5, *IML*-11, *AML*-1, *RC*-6), medium for "partially linked" (*RL*-3, *IML*-7, *AML*-0.5, *RC*-4), and lowest for "not link" (*RL*-0, *IML*-0, *AML*-0.1, *RC*-0). The "not link" code for *RL* and *IML* was suggested to decrease *CMP*, while for AML, the "no link" value was not an inevitable obstacle for *CMP.* Weights were chosen in order to obtain unique *CMP* values by different combination of variable and category, except for *IML* and *RL* were not linked. The calculated *CMP*-values, represented no (0), very low (3-8), low (9-17), medium (22-39) and high (55-61) *CMP*.

Stakeholders' challenges and expectations of connectivity science

Key challenges represented the most urgent issues that stakeholders felt needed to be solved. The codes and categories were prioritized based on the strength of linkage between connectivity' and key challenges. Key challenges were also analysed according to perceptions of connectivity, institutional adherence and the combination of both factors. Chi-squared test was used to compare between different stakeholder groups.

Information on stakeholders' expectations of connectivity science were handled by categorizing the quotes according to data/methods, knowledge transfers and communication.

Results

Direct perception of connectivity

Only 33% of stakeholders were familiar with the term "water/sediment connectivity" (Table 1, question 16), and primarily described connectivity as a connection (impact, link, relationship, relation, response, transfer/transport, fluxes) between landscape elements, or between sources and outlets via sediment and/or water pathways or routes (Figure 2A). Soil erosion and deposition were commonly mentioned as a part of their understanding, with 'connectivity' defined as the link between them. Others described connectivity by naming landscape elements or landforms (e.g., "mountains-plains via rivers"), while others understood connectivity as a continuum. Only 5% of stakeholders explained connectivity with regard to catchment management, use of water resources, or effect of water and sediment on infrastructure. These stakeholders with direct perception of connectivity were mostly farmers, employees of administration for water resource and land management, and environmental administration, working in implementation and/or in decision making around management.

Indirect perception of connectivity

In total, 86% of stakeholders observed links within landscapes, with "water flux, sediment flux, and erosion" being the most frequently named among stakeholders regardless of whether they defined connectivity (Figures 2B, 2CB). Links between landscape elements (e.g., "mountains-plains via rivers", "reservoir – water -irrigation lands located downstream", or "agricultural land-water- pollutants- fertilizer") were observed more frequently by stakeholders who did not defined connectivity. Approximately half of the observed links did not relate to water and sediment connectivity, but rather, were related to communication, cooperation or policy structures (categorized as “other” in Figure 2). One-fifth of named links were only partially related to connectivity.

The stakeholders (39%) who identified links considered as “well” or “partially” related to connectivity are thought to perceive connectivity indirectly; half of these stakeholders were farmers, while one-third were employees of environmental administrations. This 39% of stakeholders were involved with the implementation of water and land management or decisions surrounding such issues in their profession. Almost 50% worked at local scale.

Key challenges for water and land management and perceptions of connectivity

Less than half (44%) of 252 challenges related to water quality (pollution, 6%) and water quantity (availability, irrigation, drought, together 16%), soil quality (fertility, physical properties, together 8%) and soil erosion (degradation, sediment transport by water, together 9%), climate change (and weather conditions, together 2%) and connectivity of water and sediments (1%). The remaining 56% related to management, data/methods, communication/transfer of knowledge, institutions/cooperation, funding, policy, and costs and revenues of agricultural production (described as ‘farm economics’ in Table 4). The management category included challenges such as “establishment/application/maintenance of measures in flood risk mitigation, soil conservation, irrigation”, “ensuring best practice and good provision of ecosystem services”, etc. It was the most important challenge for agricultural and environmental administrators, as well as water and land managers. The agricultural administrators (predominantly located in Spain, Bosnia and Herzegovina) were challenged by non-/existing policies and their implementation, cooperation with other stakeholders (including property rights issues), and unavailability of data or proper methods for management decisions and their monitoring. Ten environmental administrators from different countries were equally concerned with management, communication, and knowledge transfer between stakeholders (ranging from policy makers to citizens), which appear to play an important role in applying and maintaining management decisions. Equally important to the large concerns about water quality and quantity were: policies, reduced funding for work, and unavailable or inappropriate data/methods. For stakeholders in water and land administration, with 50% from Spain and the remaining from different countries, water quantity and management were the most important issues. Water quantity was most important for farmers, followed by soil erosion, management, soil quality, and farm economics. For farmers from the Mediterranean region (27 of 32), water quantity, availability, drought and irrigation were more important, whereas the four farmers from areas of Central Europe with more precipitation were concerned with soil erosion, nutrient depletion, or fertilizers from fields. Contrary to both groups, an Icelandic cattle farmer working in permanent grasslands was mainly challenged by changing climate and unpredictable weather. The remaining stakeholders from multiple institutions (Table 4) were mainly concerned with availability and quality of data and methods, which seemed to be less accessible for them compared to those in administration. For 91% of stakeholders, key challenges were closely related to their daily tasks (question 3, Table 1). A distinction (not significant at $p<0.01$) can be made between farmers and administrators in regards to the perception-challenge relationship. Farmers who derived connectivity perceptions empirically (50% of them had indirect perception) directly faced daily connectivity-related challenges (Table 4). This was also true for farmers lacking observation of landscape linkages, but were still concerned about water quantity. On the other hand, the majority of administrators prioritized challenges that were indirectly or vaguely linked to connectivity issues, such as management, cooperation, communication, policies and funding, and data and applied methods. This was true regardless of whether they had direct (except in water and land management), indirect or no perception. These contrasting viewpoints illustrate some limitations and barriers posed by the institutional frameworks of each stakeholder when attempting to apply knowledge of connectivity.

Importance of connectivity management

In total, 78% of stakeholders were unaware of recent developments in connectivity research despite over half of them were thinking that connectivity played a large or small role in their management. Almost all stakeholders who recognized connectivity related linkages stated that such linkages influenced their management, while two-thirds actually managed them. In total, 63% of all stakeholders had no (24%), very low (27%) or low (12%) potential to manage connectivity (*CMP*). Environmental administrators mainly had medium *CMP*, while stakeholders in water and land management administration had very low *CMP* (Figure 3). In total, 26% of stakeholders had high *CMP* and were farmers working at local scale and administrators working at regional scale. Stakeholders with high *CMP* were primarily concerned by water quantity and/or quality and sediment fluxes, and secondly by institutional/policy/communication challenges. All stakeholders with high *CMP* used spatial data, many used monitoring data, and almost half of them collected the data themselves. Three of 22 stakeholders in this group applied environmental modelling. Decision making largely remained the responsibility of farmers with high *CMP*, while administrators with high *CMP* were only implementing decisions within their institutional structures and cooperation.

Half of stakeholders working locally had medium- to high-*CMP*, while this was about 10% less at regional and national scale. Most of stakeholders responsible for both implementation and decision making had medium- to high-*CMP*, but it was less for the other groups (Figure 3).

Stakeholders' expectation of connectivity science

In total, 76% of stakeholders formulated 83 different expectations of connectivity science. Majority of expectations concerned data, methodologies and their accessibility, as well as communication and transfer of knowledge. Stakeholders asked for erosion, flood, and sediment transport risk assessment maps with visualised sediment transport pathways in relation to existing infrastructures (field borders, roads, water infrastructure), and limits/thresholds expressing the conditions under which these hazards are most probable. Furthermore, they required maps for diffuse pollution of ground water along with predictive functions to assess the impact of new projects, or asked for free data from monitoring, scientific research and from existing databases. A web-based application with inbuilt connectivity tools was also requested, but stakeholders did not specify whether this should be model or indicators based. In order to ensure connectivity-integrated models and methods were applied among stakeholders, it was suggested to base them on existing or open-source and free datasets, and maintain easy and cost effective operation. The stakeholders also requested objective indicators and metrics to be embedded in policy, allowing farmers to apply connectivity, and for administrators to require that stakeholders utilize connectivity approaches.

Communication between scientists and other stakeholders

Interviewed stakeholders mainly worked with administration, entrepreneurs and scientists (Figure 4A). The majority of stakeholders worked with agencies (36%) or entrepreneurs (35%). Administrators worked primarily with entrepreneurs (44%), and farmers with agencies (38%, Data S2A). Less than one-third of all stakeholders worked with scientists. However, stakeholders involved in farming, or domains other than agricultural, water and land, or environmental administration cooperated with scientists intensively (37%). Approximately one-third of farmers stated no cooperation. Stakeholders primarily received information about their key issues from co-operators (45%), their own institutions (26%), or the Internet (15%, Figure 4B). Existing online datasets (5%), policy briefings and reports in farmers' journals (8%) were used relatively less often. Similarly, use of scientific publications and reports as resources (9%) was limited due to limited or no access, overly complex writing/analysis, and lack of practical applicability. A farmer explained that it was the practical demonstrations of rainfall simulation, that convinced him to apply conservation agriculture, rather than scientific publications. Despite differences in information resources used for stakeholder groups (statistically insignificant at $p<0.1$, Data S2B), all groups indicated that impacts of science would increase if stakeholders' perspectives became the centre of the topic, and/or if examples of successful management were provided. Providing training for newly developed tools and including stakeholders into teams that prepare reports and publications was suggested as a means to improve knowledge transfer.

Discussion

Limitations of the sampling strategy

Results of the questionnaire only provide insights within similar frameworks to our applied sampling approach. The sampling strategy, based on personal networks of volunteer scientists, led to preferential selection of persons within each scientist's professional network. It eliminated groups having less direct contact with scientists, such as stakeholders in national or international administration and policy-making roles. Sampling strategy based on voluntary activity of interviewers led to relatively small (85 stakeholders) and unbalanced (46% stakeholders from Spain, and 38% farmers) dataset, which cannot be considered as representative on European, nor country level, but remains appropriate for explanatory analysis. In our study, we ensured involvement of stakeholders from different countries with unique educational, institutional, political, societal and economic contexts. This diversity in perceptions and mental models introduced heterogeneities in the perceptions and motivations for adopting a connectivity management. The effects of such diversity has been widely documented (e.g., Steinhäußer et al., 2015; Prager & Curfs, 2016) in with datasets that were restricted, both spatially (e.g., region in Subirós et al., 2016) or institutionally (e.g., farmers in Andalusia, Spain in Areal & Riesgo, 2014).

Hypotheses

The observed dominance of indirect perceptions of connectivity among stakeholders confirmed our first hypothesis. Stakeholders described landscape links similarly regardless of whether they had direct or indirect perception of connectivity. The connectivity descriptors contained some scientific terms, e.g., “water and sediment fluxes”, but none of them were similar to the current academic definition provided in the introduction section (Connecteur WG Theory, 2016). Stakeholders did not adopt the academic understanding of connectivity, despite one-fifth of stakeholders having previous work with scientists; and one-third having previous involvement in projects with ties to connectivity. Areal & Riesgo (2014) demonstrated that perceptions and motivations for management adoption are influenced by neighbouring conditions, which was supported here by Mediterranean region- and Central-European farmers having perceptions of landscape linkages in line with their own key challenges, which in fact are the underlying motivation for whether management is adopted.

Stakeholders’ perceptions of fluxes, water and sediment transfer, and their uneven spatiotemporal distribution were strongly related to the connectivity concept (Connecteur WG Society, 2016), and thus represented existing background to understand and adopt connectivity concepts. Application of our proposed connectivity management potential (*CMP*) index allowed us to clearly distinguish stakeholders with different degrees of connectivity management potential. Despite being unaware of recent developments in connectivity research, two-thirds of stakeholders managed connectivity related linkages, thus confirming our second hypothesis. Additionally, over 25% of stakeholders found connectivity management an important piece in successful management decisions. This result is critical for improving knowledge and/or technology transfer between academics and end-users. Furthermore, we suggest applying the index proposed herein for simple assessments of stakeholders' connectivity management potential. Despite, connectivity management potential index should not be exchanged for in-depth analysis of stakeholders' perception, motivation and management adoption barriers in concrete projects, proposed index might be applied as a part of the analysis. Based on our results, stakeholders with high connectivity management potential may be more successful partners resulting from their willingness to apply connectivity-focused management.

Next steps for moving forward

Within our results lies a strong message regarding connectivity-related management. Despite differences in connectivity perceptions, perceived connectivity-related challenges and differing management potentials, a majority of administrative actors found it difficult to execute properly connectivity-related management due to constraints from within sectors/institutions, along with limitations of existing policies or a complete lack thereof. Regulatory measures also limited farmers that were within their domain of influence. Additional limitations stemmed from a lack of access to data and connectivity-related methods/models/maps within their institutions. Despite stakeholders' motivations to apply management approaches cannot always be related economic advantages, policies or incentives (e.g., Howley et al. 2015), institutional and policy based limitations of management influence actual implementation of connectivity related decisions (Kininmonth et al., 2015; Verbrugge et al., 2017). Conversely, many connectivity-related approaches and concepts are known to be applicable to existing policies and directives (e.g., connectivity indices in Heckmann et al., submitted), databases for management decisions (soil connectivity in soil databases, Fernández-Getino & Duarte, 2015), water-management approaches (Fryirs & Brierley, 2016), and sustainable governance (e.g., ecological connectivity -Kininmonth et al., 2015).

In order to ensure connectivity approaches and tools are transferred to stakeholders, it is necessary to actively engage stakeholders preparing legislation, standards and/or guidelines, as well as policy makers. According to Bouma & Montarella (2016), scientists play a specific role in linking policy and stakeholders in environmental management issues, but it is first necessary to intervene with the cycle of policy-making. This includes signalling (e.g., identifying problems, defining goals), through design and decision, to implementation. Such cooperation proved to be effective on multiple scales (Bouma & Montarella, 2016) and should be applied at international and EU level considering the legislative environment in Europe. This process would actively engage connectivity scientists in order to prepare new policies (e.g., in connection to European Commission Soil Thematic Strategy).

Conclusion

Studying European stakeholders' perception of water and sediment connectivity proved that both direct and indirect perceptions of connectivity exist among stakeholders involved in water and land management. Furthermore, the results demonstrated stakeholders' potential and willingness to manage connectivity more efficiently. It also revealed heterogeneity in connectivity-related challenges between different groups, but pinpointed that despite being perceived differently, they are often related or the same issue. These issues were primarily water quantity, soil erosion, sediment transport, soil and water quality, data and methods availability, communications, policies and institutions. Increased understanding of connectivity and its role in management may result from focusing on knowledge transfer within case studies, and from demonstrating connectivity-related issues, methods and tools described from stakeholders' viewpoint. Improving data availability and cost- and labour-effective tools/models, together with including stakeholders in common project and development of connectivity management tools would improve their applications. Additionally, exchange between policy makers and scientists appears essential for improving or creating successful policies and political instruments applicable to all relevant parties. Such exchange would dissolve or reduce obstacles that are hindering the potential for linking recent connectivity research developments to practical application, and enhance the potential for effective management from European stakeholders in water and land management.

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Table 1. Questionnaire given to stakeholders

No.	Question	Purpose
1	Please state the type of authority/agency/company/farm you are working for.	statistics, testing: H2
2	How long are you working in this job?	statistics
3	Briefly describe what you're doing – what are your day to day tasks	statistics, testing: H1, H2
4	What would describe your role in land and/or water management best? Multiple choice: 1. implementation of water and land management issues; 2. decision-making on water and land issues; 3. management of individual sectors (e.g. farm); 4. others, please specify	statistics, testing: H1, H2
5	On which spatial scale are you mainly working? Multiple choice: 1. local, 2. urban, 3. regional, 4. national, 5.global/international, 6. others, please specify	statistics, testing: H1, H2
6	Do you collect data on land and water management yourself, and if yes what kind?	statistics, testing: H2
7	Do you also employ environmental modelling or remote sensing data analysis in your work? If yes, what kind? Write down name of model or type of remote sensing data	statistics, testing: H2
8	What other kind of data do you use for your work in land or water management and where do you get them from?	statistics, testing: H2
9	Who do you interact with in water or land management issues within your organisation or company?	statistics
10	Who do you interact with in water or land management issues outside your organisation or company?	statistics
11	Where do you normally get your information on current land and water management issues from?	statistics
12	What do you see as the three biggest management challenges you're facing in your work in regard to water and land management? Please give a list of 3 headings.	statistics, testing: H1
13	For farmers: what kind of links or transfer routes do you see between different parts of your land? For employees in the public/private sector: with which links or transfers between different parts of the landscape is your work concerned with?	statistics, testing: H1
14	Do you see these links or transfers as important when you manage/assess the land/landscape? If yes, please give me an example?	statistics, testing: H1, H2
15	Do you actively manage the linkages? If so, why?	statistics, testing: H1, H2
16	Have you heard the term water/sediment connectivity, and if yes, what do you understand by connectivity? *	statistics, testing: H1
17	Do you think that connectivity has any role in your management?	statistics, testing: H1, H2
18	Are you aware of current connectivity research developments? If the interviewee is into monitoring: how do you incorporate connectivity features in your monitoring schemes? If the interviewee is into modelling: how do your models reproduce connectivity features? If the interviewee is into farming: what do you do to prevent or enhance connectivity (e.g. contour farming, limitation of nutrient export)	statistics, testing: H2
19	What other kind of information would be helpful for your work (which the academia could supply)?	statistics
20	What is your educational background? And gender?	statistics

* If stakeholders were interested, the interviewer explained the term to them using examples; statistics – is used for objectives 1-4 (see section 1), H1, H2 – hypotheses1 and 2 stated in section 2.

Table 2. Stakeholders sampling according to institutional adherence

Sector	Specification
1. Agriculture	1.1 Local, municipal, regional and/or national agricultural administration
	1.2 Farmer, farm managers, farmer advisers
	1.3 Regional farmers' associations
2. Water and land management	2.1 Local, municipal, regional, and/or national administration for water resource and land management, coastal protection
	2.2 Local, municipal, regional, and/or national water body maintenance and irrigation associations
	2.3 Water supply companies
	2.4 Energy plant managers
3. Cross-sector	3.1 Local, municipal, regional, and/or national environmental administration
	3.2 Local, municipal, regional, and/or national planning administrations
	3.3 Local, municipal, regional, and/or national tourism associations
	3.4 Environmental protection NGOs
	3.5 Consultancy companies in water and land management, agriculture or environment
4. Others	4.1 Local, municipal, regional, and/or national forest management administration
	4.2 Local, municipal, regional, and/or national soil conservation administration

Table 3. Stakeholders' dataset

1. Country of origin

	Spain	Bosnia and Herzegovina	Turkey	Portugal	Group 1	Group 2
% of stakeholders*	46	11	6	5	4	1

2. Gender

	Male	Female	ND
% of stakeholders	65	15	20

3. Education by level

	No tertiary	University	PhD	ND
% of stakeholders	20	60	14	6

4. Education by subject

	Agriculture	Watershed management / Hydrology	Civil Engineering	Physical Geography	Others	ND
% of stakeholders	25	8	8	6	13	40

5. Stakeholder group (type of institution in Table 2)**

	Farmers (1.2 / 1.3)	Administrators (1.1 / 2.1 / 3.1)	Others (2.2 / 2.3 / 2.4 / 3.2 / 3.3 / 3.4 / 3.5 / 4.1 / 4.2)
% of stakeholders	37.65 / 0	8.5 / 11.9 / 8.5	0 / 0.85 / 0 / 4.25 / 0 / 2.55 / 3.4 / 3.4 / 0.85

6. Role in water and land management

	Implementation of decision	Decision making	Management of individual sector	Combination of previous	Others
% stakeholders	29	31	13	16	12

7. Collection of data by stakeholders ***

	No	Yes (62%)				
		Water quality	Water quantity	Run-off	Water infrastructure	Soil properties
		20	18	7	8	19
		Land use /vegetation	Weather	Finance	Spatial specific data	
% of stakeholders	38	25	14	2	5	

8. Use of spatial information and environmental models ***

	No	Yes (48%)				
		Spatial data (GIS)	Remote sensing	ND	Other members of working group	Environmental modelling
% of stakeholders	52	15	24	2	13	25

% of stakeholder from total number 85 is indicated. One stakeholder corresponds to .0.85%. Number /% of stakeholders corresponds to number / % of questionnaires conducted. ND-no data
* - % of stakeholders coming from each country named; Group 1- Finland, Germany, Italy, Poland Slovakia, United Kingdom, Group 2- Austria, Belgium, Estonia, France, Hungary, Iceland, Ireland, Norway;
**- categories refer to stakeholder group (Table 4, Figure 4, Data S2), number in brackets to institutions (Table 2), farmers are 27.2% of all stakeholders, administrators 28.9%, and others 22.35%
***-multiple types of data collected/used were stated by stakeholders

Table 4. Stakeholders' key challenges according their institution and connectivity perception

	Administration																								
Institution	Agricultural				Water & Land				Environmental				Farmers				Others				Total			
Perception	D	I	N	L	D	I	N	L	D	I	N	L	D	I	N	L	D	I	N	L	D	I	N	L
Stakeholders count	1	3	6	10	6	6	2	14	5	4	1	10	6	16	10	32	10	3	6	19	28	32	25	85
Challenge	Challenge named (%)*																							
Connectivity	-	-	-	-	-	-	-	-	7	-	-	3	-	-	-	-	3	-	-	2	2	-	-	1
Water quality	-	-	6	7	28	-	-	12	13	17	-	13	-	-	7	2	3	11	13	7	10	3	7	6
Water quantity	-	-	11	3	22	22	17	21	13	-	33	10	11	23	17	19	13	11	20	15	14	17	17	16
Soil quality	-	-	11	7	6	-	-	2	-	-	-	-	22	15	10	15	10	-	7	7	10	7	8	8
Soil erosion	-	-	-	-	6	-	-	2	7	8	-	7	33	21	3	18	3	-	13	6	11	11	4	9
Climate change	-	-	6	3	-	-	17	2	-	-	-			-	7	2	-	-	-	-	-	-	6	2
Management	-	56	22	30	6	22	67	21	13	25	-	17	22	13	17	16	10	11	13	11	12	20	21	17
Policy	-	11	17	13	-	-	-	-	-	8	67	10	-	-	7	2	3	22	7	7	1	4	11	5
Institution/ Cooperation	33	11	6	10	6	22	-	12	-		-	0	-	2	-	1	17	11	-	11	8	7	1	6
Funding		-	6	3	-	6	-	2	7	25	-	13	-	-	3	1	17	-	-	9	7	4	3	5
Communication / Knowledge transfer	33	11	6	10	22	11	-	14	27	8	-	17	11	0	3	3	3	-	-	2	14	4	3	7
Data / Methods	33	11	11	13	6	17	-	10	13	8	-	10	-	8	10	7	17	33	20	20	11	13	11	12
Farm economics	-	-	-	-	-	-	-	-	-	-	-	-	-	19	17	15	3	-	7	2	-	9	8	6

Perception: D- direct, I- indirect, N- no perception, L-all stakeholders in a group independently on their perception of connectivity; *each stakeholder named 3 challenges and the percentage was calculated as the sum of challenges named by stakeholders in each category (defined by institution and perception). Differences between groups were not statistically significant (p>0.01)

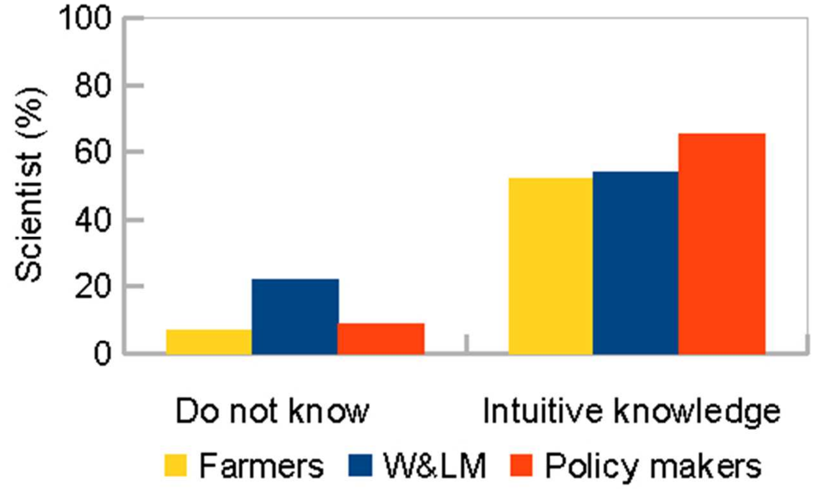

Figure 1. Poll among 46 connectivity scientists about stakeholders' perception (2nd MC Meeting of EU COST Action ES 1306 Connecteur, 16-17/09/2015, Durham, UK). Percent of scientists who answered positively to the following statements is plotted on the Y-axis: 1. (left) "Stakeholders in water and land management (W&LM) do not know what water and sediment connectivity is", 2 (right): "Stakeholders in W&LM having some intuitive knowledge on connectivity". Questions were asked separately for three stakeholders' groups: farmers, water and land managers, and policy makers.

80x50mm (200 x 200 DPI)

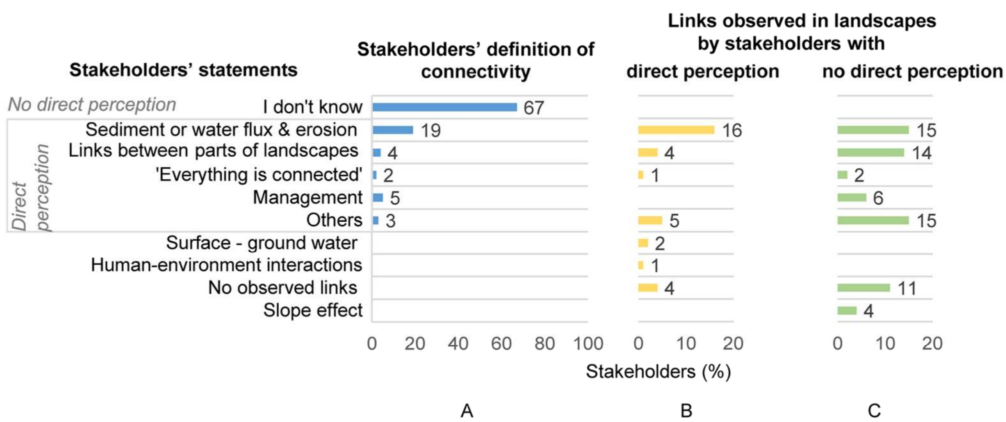

Figure 2. Results from the stakeholder questionnaire summarizing the answers regarding stakeholders' direct (A) and indirect (B, C) perception of water and sediment connectivity. B. Links observed by stakeholders who defined water and sediment connectivity. C. Links observed by stakeholders who did not define water and sediment connectivity.

69x32mm (600 x 600 DPI)

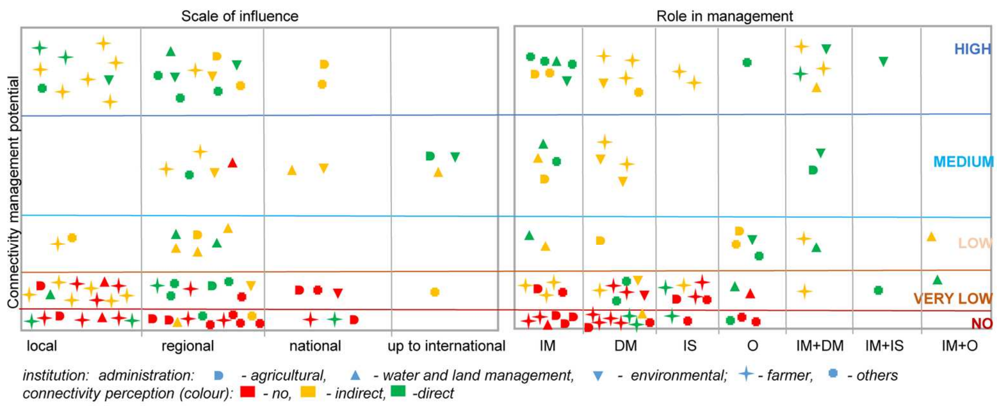

Figure 3. Stakeholders' connectivity management potential, calculated from the answers on stakeholder questionnaires about recognition and management of connectivity related linkages and connectivity. Calculation is based on index of connectivity management potential (eq. 1).

80x37mm (600 x 600 DPI)

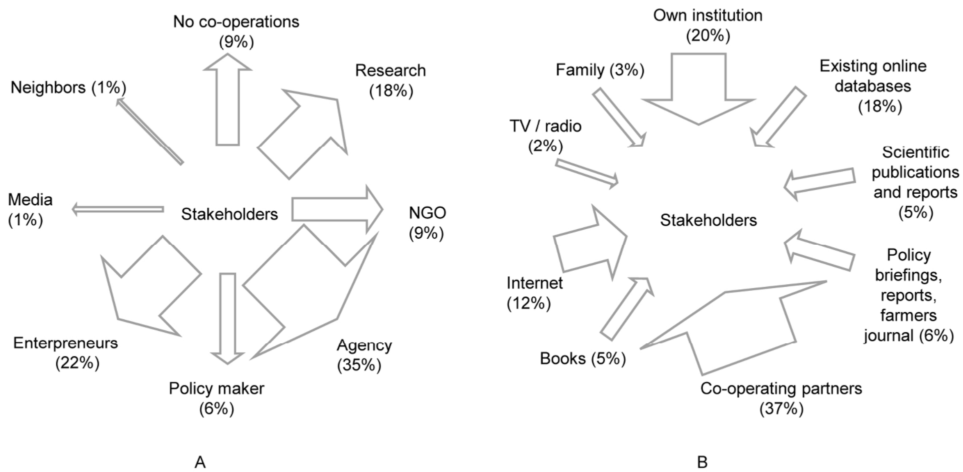

Figure 4. Results from the stakeholder questionnaire summarizing answers about stakeholders' cooperation (A) and information resources (B). The width of arrow is scaled representing indicated percentage.

100x58mm (600 x 600 DPI)