

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

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4 30 Abstract

5 31 Using concepts of connectivity in challenges regarding land and water management (flooding,  
6 32 erosion, nutrient leaching, landslides) can only be fully harnessed if knowledge is  
7 33 communicated well between scientists and stakeholders. Proper communication requires prior  
8 34 understanding of end-users' perception of connectivity as a useful framework. Therefore, we  
9 35 analysed (i) perceptions of 'connectivity' for stakeholders involved in water and land  
10 36 management across Europe, (ii) potential for stakeholders to apply connectivity-related  
11 37 measures in their management decisions, (iii) stakeholders' biggest challenges in water and  
12 38 land management, and (iv) stakeholders' expectations for future 'connectivity' research  
13 39 agendas. We studied 85 questionnaires from 19 countries using a grounded theory approach.  
14 40 One-third of stakeholders understood connectivity in its scientific context, while 39% perceived  
15 41 connectivity indirectly through their personal experiences (e.g., water and sediment fluxes and  
16 42 erosion). Half of stakeholders' perceived links and challenges were related to availability of data  
17 43 and methods, communication, and institutions or policy, while others believed they were related  
18 44 to water quality and quantity, soil erosion and quality, and climate change. Half of the  
19 45 stakeholders considered connectivity management important, and one-third showed high  
20 46 interest in managing connectivity. Adopting connectivity into management is hindered by  
21 47 institutional- and policy-based management limitations, insufficient data and methods, and  
22 48 ineffective knowledge transfer. Explicitly considering heterogeneity of stakeholder perceptions is  
23 49 required for projects regarding management of connectivity at European, national and local  
24 50 scales.

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

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55 Introduction

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57 Research on water and sediment connectivity (furthermore- connectivity, unless noted  
58 otherwise) has received increased attention across the fields within geosciences (Bracken et al.,  
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4 59 2015; Chartin et al., 2016; Laudon et al., 2016; Masselink et al., 2016a, 2016b; Souza et al.,  
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6 60 2016; Welter & Fisher, 2016; Lane et al., 2017). Water and sediment connectivity is currently  
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8 61 defined as ‘the degree to which a system facilitates the movement of matter and energy through  
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10 62 itself; it is thought to be an emergent property of the system state’ (Connecteur WG Theory,  
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12 63 2016). Aside from academic/scientific applications of connectivity concepts, researchers have  
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14 64 acknowledged that connectivity concepts and methods have potential to supply vital tools to  
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16 65 stakeholders outside academia (furthermore -stakeholders) for tackling challenges in land and  
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18 66 water management such as flooding, nutrient and contaminant leaching, reservoir  
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20 67 sedimentation, habitat fragmentation, land degradation or landslide development (e.g., Gay et  
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22 68 al., 2016; Mekonnen et al., 2016; Tiranti et al. 2016, Vigiak et al., 2016; Poepl et al., 2017).  
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24 69 European scientists are aiming to transfer contemporary connectivity tools to applied sciences  
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26 70 and stakeholders working in water and land management (Connecteur WG Society, 2016).  
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28 71 Despite numerous studies using stakeholder analysis to investigate stakeholders’ perceptions of  
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30 72 water and land management, conflict negotiations and participatory environmental management  
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32 73 and policy (e.g., Grimble & Chan, 1995; Reeds et al., 2009; Lestrelin et al., 2012; Sjögersten et  
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34 74 al., 2013; Tripathi et al., 2014; Steinhäuser et al., 2015; Bouma & Montarella, 2016; Nigussie et  
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36 75 al., 2016, Shikangalah et al., 2016; Subirós et al., 2016), it remains unclear how connectivity is  
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38 76 integrated in stakeholders’ understanding of water and land management across Europe.  
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40 77 Furthermore, little is known on how connectivity and recently developed connectivity tools  
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42 78 (including highly specialised methods for connectivity measurement approaches, connectivity  
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44 79 modelling and indices of connectivity) are applied to management challenges by stakeholders.  
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46 80 Differences in perceptions of an observable phenomena (e.g., connectivity, health, policy  
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48 81 adoption, land degradation, flooding) play an important role in interpreting that phenomenon and  
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50 82 the attitude that is adopted towards it (e.g., Abbott et al., 2006; Herzfeld & Jongeneel, 2012;  
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52 83 Tripathi et al., 2014; Assefa & Bork, 2015), and together with inadequate knowledge transfer  
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54 84 may complicate even the best management practices for tackling environmental problems  
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56 85 (Fazey et al., 2013; Prager & Curfs, 2016). Therefore, for successful knowledge and technology  
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58 86 transfer of connectivity concepts and tools in Europe, it is of particular importance to first  
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60 87 determine differences in perceptions of connectivity, especially as they relate to perception in

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4 88 conditions of existing environmental, cultural, historical, societal and institutional diversity,  
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6 89 where stakeholders are to a certain extent tied by common EU legislation (e.g., Water  
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8 90 Framework Directive, Common Agricultural Policy). Therefore, the objectives of this study are (i)  
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10 91 to analyse perceptions of 'connectivity' for stakeholders involved in water and land management  
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12 92 across Europe, (ii) to evaluate stakeholder's potential to apply connectivity related measures in  
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14 93 their management decisions, (iii) to discuss the biggest challenges in water and land  
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16 94 management, and (iv) to summarize stakeholders' expectations of the current connectivity  
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18 95 research agenda.

## 19 20 96 21 22 97 Methods

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25 99 This research is embedded in the European Union (EU) COST Action ES 1306 Connecteur  
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27 100 project (furthermore Connecteur), representing a network of researchers and practitioners from  
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29 101 EU and associated countries working on connectivity. This group of collaborators was used to  
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31 102 help define data collection set-up and methods described below, which apply a network  
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33 103 approach to qualitative stakeholder analysis.

## 34 104 35 105 *Questionnaires*

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38 107 The perceptions (i.e., the ideas and notions of a topic that someone has awareness of) of  
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40 108 academics (furthermore; scientists) and stakeholders greatly differ on a range of environmental  
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42 109 issues (Prager & Curfs, 2016). Thus it was expected that stakeholders are unfamiliar with  
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44 110 connectivity concepts in contemporary research. In order to formulate questions investigating  
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46 111 stakeholders' perceptions, two hypotheses were followed.

47 112 *Hypothesis 1: Stakeholders primarily have perceptions of connectivity based on empirical*  
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49 113 *experiences and only in relation to their own challenges.* Empirical experience is hereby  
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51 114 understood as accumulated knowledge or skills derived from observation through participation  
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53 115 in life events or activities.

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4 116 The majority of 46 scientists polled at the 2<sup>nd</sup> MC Meeting of Connecteur (16-17/09/2015,  
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6 117 Durham, UK) expected that stakeholders to have intuitive knowledge on connectivity, confirming  
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8 118 the credibility of this hypothesis (Figure 1). The hypothesis (partially) represents one mental  
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10 119 model held by European connectivity scientists on stakeholders' perceptions of connectivity  
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12 120 issues and relates to the first objective of the study. The questioned scientists also presumed  
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14 121 that a minor number of stakeholders were aware of current connectivity research and hardly any  
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16 122 would actively apply connectivity tools in their daily work.

17 123 Similarly, we expected that:

18 124 *Hypothesis 2: Despite stakeholders being unaware of recent connectivity research*  
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20 125 *developments, they have potential to manage water and sediment connectivity based on their*  
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22 126 *indirect perception of connectivity and current management of connectivity related issues.*

23 127 Indirect perception is understood as experience-based intuitive insight on connectivity without  
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25 128 knowledge of the scientific definition and concept of connectivity (which define direct  
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27 129 perception). This hypothesis addresses the second objective of the study. The third and fourth  
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29 130 objectives were addressed using descriptive statistics, and the remaining objectives were  
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31 131 addressed by analysis of questionnaires.

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34 133 A questionnaire of 20 questions, written in English, was developed for stakeholders, and  
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36 134 included free-response questions, closed- and multiple-choice questions (Table 1). Questions  
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38 135 were based on an interdisciplinary participatory discussion from a workshop of Connecteur  
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40 136 (Connecteur Society, 2016) in Berlin, April, 2015. The questions supporting respondents'  
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42 137 intuitive understanding and spontaneous definition of connectivity were preferred over questions  
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44 138 that may have required pre-existing scientific awareness of connectivity or interviewers'  
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46 139 perceptions. The questions included (i) general statistics about the respondents; (ii) their  
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48 140 responsibilities and spatial range of influence, (iii) the type of data they collect and/or use, (iv)  
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50 141 people and organisations they cooperate with, (v) the biggest challenges of their work in current  
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52 142 water and land management, (vi) their understanding of connectivity and its importance in  
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54 143 management, (vii) expectations of connectivity science/scientists. Prior to the interview,

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4 144 respondents were informed about the anonymity, and purpose of the interview, according to  
5 145 ethical regulations (developed by TU Berlin, Germany).

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7 146 Questionnaires were translated into 14 languages (Dutch, Estonian, Finnish, French, German,  
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9 147 Hungarian, Italian, Maltese, Polish, Portuguese, Serbian, Slovak, Spanish and Turkish) by  
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11 148 volunteer scientists from Connecteur.

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15 150 *Survey approach and stakeholder sampling*

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18 152 Any number of volunteering scientists from Connecteur were permitted to contribute to the  
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20 153 research by interviewing as many stakeholders as they chose. Thus, the number of participating  
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22 154 countries and total interviews performed were semi-random, but limited to the countries within  
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24 155 the COST network. Less than half of 29 interviewers had previous experience conducting semi-  
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26 156 structured interviews, and 66% had previous experience with stakeholders. Additional  
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28 157 information on interviewers' backgrounds in the use of applied methods and cooperating with  
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30 158 stakeholders is found in Data S1.

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33 160 A mixed-sampling approach combining the criterion- and snowball-sampling methods (Patton,  
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35 161 2002) was employed in order to include relevant stakeholders. Interviewers sampled  
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37 162 stakeholders within their own professional network and institutions (Table 2) while excluded  
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39 163 those stakeholders having direct working relationships with scientists working on connectivity  
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41 164 topics. We provided interviewers with guidelines for the interview format, questions to ask, and  
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43 165 the important components to be extracted from the questionnaires. Questionnaires were  
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45 166 performed in person or via phone or email, depending the individual stakeholder's preference  
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47 167 and options available to the interviewer. Because recording equipment was unavailable, we  
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49 168 used both transcribed and summarized interviews that were translated to English by the  
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51 169 interviewers.

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57 172 *Dataset*

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4 173 A total of 85 stakeholder questionnaires were implemented by 29 different interviewers from 19  
5 174 European countries (46% stakeholders from Spain, 11% from Bosnia and Herzegovina, with the  
6 175 remaining 43% from other countries, Table 3). Most commonly respondent were males having  
7 176 tertiary education or PhDs, and with an average of 18 years working experience. Respondents  
8 177 were mainly administrators (44%) and farmers (38%). A description of the dataset compiled  
9 178 from questionnaires is available in Table 3. Stakeholders answered from 93 to 100% of 20 total  
10 179 questions. For questions 8, 14 and 15 (Table 1), 11-15% of stakeholders did not provide a  
11 180 response.

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### 14 183 *Data evaluation*

15 184 Data was evaluated using grounded theory, an inductive technique for interpreting recorded  
16 185 data about a social phenomenon (Glaser & Strauss, 1967), applying the coding approach  
17 186 described in Strauss & Corbin (1990, 1998) as follows. Coding involves classifying and  
18 187 categorizing text data segments into a set of (i) codes, (ii) categories, and (iii) relationships.  
19 188 Firstly, an open coding procedure identified key ideas and perceptions hidden within the text  
20 189 data. A code representing the basic concept of a portion of a text was assigned to it. Each  
21 190 individual code originated from the text, using respondents' or researcher wording to define the  
22 191 code definitions. This process was continuous and the number of codes increased with the  
23 192 portion of analysed text. Secondly, similar codes were categorized to represent specific and  
24 193 meaningful concepts. Open coding, categorization, and axial coding were performed  
25 194 simultaneously. Axial coding targeted the analysis of relationships between concepts and  
26 195 constructs. The selective coding procedure prioritized categories, enabling identification of  
27 196 categories relevant to the research questions, and the ability to link them to the remaining  
28 197 categories. Identified codes, categories and relationships were further analysed by mixed  
29 198 quantitative and qualitative approach consisting of (i) frequency statistics of categories, (ii) story  
30 199 lining (using concepts and constructs to refine outlined stories), and (iii) visualising the  
31 200 relationships.

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4 202 *Analysis of stakeholders' perception*

5 203 In order to test the first hypothesis, we assumed that stakeholders' definition of water and  
6 204 sediment connectivity (Table 1, question 16) referred to their direct perception of connectivity.  
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8 205 Furthermore, we suggest that links in a landscape described by stakeholders (Table 1, question  
9 206 13) provide insight to how stakeholders perceive landscape functionality, as well as  
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11 207 accumulated indirect knowledge of water and sediment connectivity. Described links were proof  
12 208 of indirect observations or knowledge of water and sediment connectivity. The codes describing  
13 209 the identified links were ranked- in relation to connectivity- as "well linked", "partially linked" or  
14 210 "not linked". "Well linked" descriptions were those acknowledging the existence of fluxes and  
15 211 linkages between landscape compartments, and/or their spatial and temporal variability.  
16 212 "Partially linked" descriptions included those that mentioned landscape units without a specific  
17 213 type of link, described management effects on natural systems, or used phrases such as  
18 214 "everything is connected". The last category, 'not linked', contained answers such as "no, none,  
19 215 and/or not relevant", or when no response was provided. Stakeholders' perception was further  
20 216 analysed in the context of the main challenges described below.  
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32 218 *An index for measuring Connectivity Management Potential*

33 219 In order to test the second hypothesis, an index of connectivity management potential (*CMP*)  
34 220 was proposed as follows  
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$$CMP = RL \times IML \times AML + RC$$
 (eq.1),  
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43 224 where: *RL* is recognising linkages related to connectivity (based on answers to question 13 in  
44 225 Table 1), *IML* is recognising the importance of connectivity related linkages in management  
45 226 (Table 1, question 14), *AML* is actually practicing management of connectivity related linkages  
46 227 (Table 1, question 15), and *RC* is recognising the role of connectivity in management (Table 1,  
47 228 question 17).

48 229 *CMP* reflected the influence of perceived value (*IML*) and knowledge (*RL*) for adoption of  
49 230 environmental management decisions (e.g., Greiner & Greg, 2010; Kragt et al., 2017). The *IML*

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4 231 was presumed to be more relevant for *CMP* than *RL* and *AML* ( $AML < RL < IML$ ), and *IML* and  
5 232 *RL* limiting for *CMP*. *RC*- linked to direct perception of connectivity, was expected, but not  
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7 233 100%, to have additional benefits to *CMP*, and was therefore expressed by addition' rather than  
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9 234 multiplication.  
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11 235 Evaluation of stakeholders' answers to questions 13-15 and 17 (Table 1) is described in the  
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13 236 "*Data evaluation*" section. First, we evaluated the ability to contextualize meanings of the  
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15 237 variables (i.e., *RL*, *IML*, *AML*, and *RC*) using abbreviated 'coded' phrase. Descriptive categories  
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17 238 were assigned with quantitative values in order to express the agreement between the variables  
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19 239 and the final coded phrase. Categories assigned to each variable included 'well linked' (> 50%  
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21 240 agreement), 'partially linked' (25-50% agreement), and 'no link' (0-25% agreement).  
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23 241 Subsequently, a unique numerical weight was assigned to each variable and category of codes  
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25 242 in order to obtain unique *CMP* values. The weights were chosen in order to represent the  
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27 243 ranking according to the relevance to *CMP* ( $RC < AML < RL < IML$ ). Weights were chosen in  
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29 244 order to obtain unique *CMP* values by different combination of variable and category, except for  
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31 245 *IML* and *RL* were not linked. Unique values of *CMP* were produced solely for ranking purposes  
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33 246 and demonstrating differences between stakeholders' groups. The code's ranking ranged from:  
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35 247 highest for "well linked" (*RL*-5, *IML*-11, *AML*-1, *RC*-6), medium for "partially linked" (*RL*-3, *IML*-7,  
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37 248 *AML*-0.5, *RC*-4), and lowest for "not link" (*RL*-0, *IML*-0, *AML*-0.1, *RC*-0). The "not link" code for  
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39 249 *RL* and *IML* was suggested to decrease *CMP*, while for *AML*, the "no link" value was not an  
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41 250 inevitable obstacle for *CMP*. Weights were chosen in order to obtain unique *CMP* values by  
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43 251 different combination of variable and category, except for *IML* and *RL* were not linked. The  
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45 252 calculated *CMP*-values, represented no (0), very low (3-8), low (9-17), medium (22-39) and high  
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47 253 (55-61) *CMP*.

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255 *Stakeholders' challenges and expectations of connectivity science*

256 Key challenges represented the most urgent issues that stakeholders felt needed to be solved.  
257 The codes and categories were prioritized based on the strength of linkage between  
258 connectivity' and key challenges. Key challenges were also analysed according to perceptions

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4 259 of connectivity, institutional adherence and the combination of both factors. Chi-squared test  
5 260 was used to compare between different stakeholder groups.  
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7 261 Information on stakeholders' expectations of connectivity science were handled by categorizing  
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9 262 the quotes according to data/methods, knowledge transfers and communication.  
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12 264 Results

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14 266 *Direct perception of connectivity*

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18 267 Only 33% of stakeholders were familiar with the term "water/sediment connectivity" (Table 1,  
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20 268 question 16), and primarily described connectivity as a connection (impact, link, relationship,  
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22 269 relation, response, transfer/transport, fluxes) between landscape elements, or between sources  
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24 270 and outlets via sediment and/or water pathways or routes (Figure 2A). Soil erosion and  
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26 271 deposition were commonly mentioned as a part of their understanding, with 'connectivity'  
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28 272 defined as the link between them. Others described connectivity by naming landscape elements  
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30 273 or landforms (e.g., "mountains-plains via rivers"), while others understood connectivity as a  
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32 274 continuum. Only 5% of stakeholders explained connectivity with regard to catchment  
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34 275 management, use of water resources, or effect of water and sediment on infrastructure. These  
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36 276 stakeholders with direct perception of connectivity were mostly farmers, employees of  
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38 277 administration for water resource and land management, and environmental administration,  
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40 278 working in implementation and/or in decision making around management.  
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43 280 *Indirect perception of connectivity*

44 281 In total, 86% of stakeholders observed links within landscapes, with "water flux, sediment flux,  
45 282 and erosion" being the most frequently named among stakeholders regardless of whether they  
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47 283 defined connectivity (Figures 2B, 2CB). Links between landscape elements (e.g., "mountains-  
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49 284 plains via rivers", "reservoir – water -irrigation lands located downstream", or "agricultural land-  
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51 285 water- pollutants- fertilizer") were observed more frequently by stakeholders who did not defined  
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53 286 connectivity. Approximately half of the observed links did not relate to water and sediment  
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55 287 connectivity, but rather, were related to communication, cooperation or policy structures  
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4 288 (categorized as “other” in Figure 2). One-fifth of named links were only partially related to  
5 289 connectivity.

7 290 The stakeholders (39%) who identified links considered as “well” or “partially” related to  
8 291 connectivity are thought to perceive connectivity indirectly; half of these stakeholders were  
9 292 farmers, while one-third were employees of environmental administrations. This 39% of  
10 293 stakeholders were involved with the implementation of water and land management or  
11 294 decisions surrounding such issues in their profession. Almost 50% worked at local scale.

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18 296 *Key challenges for water and land management and perceptions of connectivity*

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20 297 Less than half (44%) of 252 challenges related to water quality (pollution, 6%) and water  
21 298 quantity (availability, irrigation, drought, together 16%), soil quality (fertility, physical properties,  
22 299 together 8%) and soil erosion (degradation, sediment transport by water, together 9%), climate  
23 300 change (and weather conditions, together 2%) and connectivity of water and sediments (1%).

24  
25 301 The remaining 56% related to management, data/methods, communication/transfer of  
26 302 knowledge, institutions/cooperation, funding, policy, and costs and revenues of agricultural  
27 303 production (described as ‘farm economics’ in Table 4). The management category included  
28 304 challenges such as “establishment/application/maintenance of measures in flood risk mitigation,  
29 305 soil conservation, irrigation”, “ensuring best practice and good provision of ecosystem services”,  
30 306 etc. It was the most important challenge for agricultural and environmental administrators, as  
31 307 well as water and land managers. The agricultural administrators (predominantly located in  
32 308 Spain, Bosnia and Herzegovina) were challenged by non-/existing policies and their  
33 309 implementation, cooperation with other stakeholders (including property rights issues), and  
34 310 unavailability of data or proper methods for management decisions and their monitoring. Ten  
35 311 environmental administrators from different countries were equally concerned with  
36 312 management, communication, and knowledge transfer between stakeholders (ranging from  
37 313 policy makers to citizens), which appear to play an important role in applying and maintaining  
38 314 management decisions. Equally important to the large concerns about water quality and  
39 315 quantity were: policies, reduced funding for work, and unavailable or inappropriate  
40 316 data/methods. For stakeholders in water and land administration, with 50% from Spain and the

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4 317 remaining from different countries, water quantity and management were the most important  
5 318 issues. Water quantity was most important for farmers, followed by soil erosion, management,  
6 319 soil quality, and farm economics. For farmers from the Mediterranean region (27 of 32), water  
7 320 quantity, availability, drought and irrigation were more important, whereas the four farmers from  
8 321 areas of Central Europe with more precipitation were concerned with soil erosion, nutrient  
9 322 depletion, or fertilizers from fields. Contrary to both groups, an Icelandic cattle farmer working in  
10 323 permanent grasslands was mainly challenged by changing climate and unpredictable weather.  
11 324 The remaining stakeholders from multiple institutions (Table 4) were mainly concerned with  
12 325 availability and quality of data and methods, which seemed to be less accessible for them  
13 326 compared to those in administration. For 91% of stakeholders, key challenges were closely  
14 327 related to their daily tasks (question 3, Table 1). A distinction (not significant at  $p < 0.01$ ) can be  
15 328 made between farmers and administrators in regards to the perception-challenge relationship.  
16 329 Farmers who derived connectivity perceptions empirically (50% of them had indirect perception)  
17 330 directly faced daily connectivity-related challenges (Table 4). This was also true for farmers  
18 331 lacking observation of landscape linkages, but were still concerned about water quantity. On the  
19 332 other hand, the majority of administrators prioritized challenges that were indirectly or vaguely  
20 333 linked to connectivity issues, such as management, cooperation, communication, policies and  
21 334 funding, and data and applied methods. This was true regardless of whether they had direct  
22 335 (except in water and land management), indirect or no perception. These contrasting viewpoints  
23 336 illustrate some limitations and barriers posed by the institutional frameworks of each  
24 337 stakeholder when attempting to apply knowledge of connectivity.

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### 339 *Importance of connectivity management*

340 In total, 78% of stakeholders were unaware of recent developments in connectivity research  
341 despite over half of them were thinking that connectivity played a large or small role in their  
342 management. Almost all stakeholders who recognized connectivity related linkages stated that  
343 such linkages influenced their management, while two-thirds actually managed them. In total,  
344 63% of all stakeholders had no (24%), very low (27%) or low (12%) potential to manage  
345 connectivity (*CMP*). Environmental administrators mainly had medium *CMP*, while stakeholders

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4 346 in water and land management administration had very low *CMP* (Figure 3). In total, 26% of  
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6 347 stakeholders had high *CMP* and were farmers working at local scale and administrators working  
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8 348 at regional scale. Stakeholders with high *CMP* were primarily concerned by water quantity  
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10 349 and/or quality and sediment fluxes, and secondly by institutional/policy/communication  
11  
12 350 challenges. All stakeholders with high *CMP* used spatial data, many used monitoring data, and  
13  
14 351 almost half of them collected the data themselves. Three of 22 stakeholders in this group  
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16 352 applied environmental modelling. Decision making largely remained the responsibility of farmers  
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18 353 with high *CMP*, while administrators with high *CMP* were only implementing decisions within  
19  
20 354 their institutional structures and cooperation.

21  
22 355 Half of stakeholders working locally had medium- to high-*CMP*, while this was about 10% less at  
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24 356 regional and national scale. Most of stakeholders responsible for both implementation and  
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26 357 decision making had medium- to high-*CMP*, but it was less for the other groups (Figure 3).

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#### 29 359 *Stakeholders' expectation of connectivity science*

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31 360 In total, 76% of stakeholders formulated 83 different expectations of connectivity science.  
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33 361 Majority of expectations concerned data, methodologies and their accessibility, as well as  
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35 362 communication and transfer of knowledge. Stakeholders asked for erosion, flood, and sediment  
36  
37 363 transport risk assessment maps with visualised sediment transport pathways in relation to  
38  
39 364 existing infrastructures (field borders, roads, water infrastructure), and limits/thresholds  
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41 365 expressing the conditions under which these hazards are most probable. Furthermore, they  
42  
43 366 required maps for diffuse pollution of ground water along with predictive functions to assess the  
44  
45 367 impact of new projects, or asked for free data from monitoring, scientific research and from  
46  
47 368 existing databases. A web-based application with inbuilt connectivity tools was also requested,  
48  
49 369 but stakeholders did not specify whether this should be model or indicators based. In order to  
50  
51 370 ensure connectivity-integrated models and methods were applied among stakeholders, it was  
52  
53 371 suggested to base them on existing or open-source and free datasets, and maintain easy and  
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55 372 cost effective operation. The stakeholders also requested objective indicators and metrics to be  
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57 373 embedded in policy, allowing farmers to apply connectivity, and for administrators to require that  
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59 374 stakeholders utilize connectivity approaches.

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5 376 *Communication between scientists and other stakeholders*

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7 377 Interviewed stakeholders mainly worked with administration, entrepreneurs and scientists  
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9 378 (Figure 4A). The majority of stakeholders worked with agencies (36%) or entrepreneurs (35%).  
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11 379 Administrators worked primarily with entrepreneurs (44%), and farmers with agencies (38%,  
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13 380 Data S2A). Less than one-third of all stakeholders worked with scientists. However,  
14  
15 381 stakeholders involved in farming, or domains other than agricultural, water and land, or  
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17 382 environmental administration cooperated with scientists intensively (37%). Approximately one-  
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19 383 third of farmers stated no cooperation. Stakeholders primarily received information about their  
20  
21 384 key issues from co-operators (45%), their own institutions (26%), or the Internet (15%, Figure  
22  
23 385 4B). Existing online datasets (5%), policy briefings and reports in farmers' journals (8%) were  
24  
25 386 used relatively less often. Similarly, use of scientific publications and reports as resources (9%)  
26  
27 387 was limited due to limited or no access, overly complex writing/analysis, and lack of practical  
28  
29 388 applicability. A farmer explained that it was the practical demonstrations of rainfall simulation,  
30  
31 389 that convinced him to apply conservation agriculture, rather than scientific publications. Despite  
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33 390 differences in information resources used for stakeholder groups (statistically insignificant at  
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35 391  $p < 0.1$ , Data S2B), all groups indicated that impacts of science would increase if stakeholders'  
36  
37 392 perspectives became the centre of the topic, and/or if examples of successful management  
38  
39 393 were provided. Providing training for newly developed tools and including stakeholders into  
40  
41 394 teams that prepare reports and publications was suggested as a means to improve knowledge  
42  
43 395 transfer.

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45 397 Discussion

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47 399 *Limitations of the sampling strategy*

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49 400 Results of the questionnaire only provide insights within similar frameworks to our applied  
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51 401 sampling approach. The sampling strategy, based on personal networks of volunteer scientists,  
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53 402 led to preferential selection of persons within each scientist's professional network. It eliminated  
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55 403 groups having less direct contact with scientists, such as stakeholders in national or



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4 404 international administration and policy-making roles. Sampling strategy based on voluntary  
5 405 activity of interviewers led to relatively small (85 stakeholders) and unbalanced (46%  
6 406 stakeholders from Spain, and 38% farmers) dataset, which cannot be considered as  
7 407 representative on European, nor country level, but remains appropriate for explanatory analysis.  
8  
9 408 In our study, we ensured involvement of stakeholders from different countries with unique  
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11 409 educational, institutional, political, societal and economic contexts. This diversity in perceptions  
12  
13 410 and mental models introduced heterogeneities in the perceptions and motivations for adopting a  
14  
15 411 connectivity management. The effects of such diversity has been widely documented (e.g.,  
16  
17 412 Steinhäuser et al., 2015; Prager & Curfs, 2016) in with datasets that were restricted, both  
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19 413 spatially (e.g., region in Subirós et al., 2016) or institutionally (e.g., farmers in Andalusia, Spain  
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21 414 in Areal & Riesgo, 2014).

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#### 25 416 *Hypotheses*

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27 417 The observed dominance of indirect perceptions of connectivity among stakeholders confirmed  
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29 418 our first hypothesis. Stakeholders described landscape links similarly regardless of whether they  
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31 419 had direct or indirect perception of connectivity. The connectivity descriptors contained some  
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33 420 scientific terms, e.g., “water and sediment fluxes”, but none of them were similar to the current  
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35 421 academic definition provided in the introduction section (Connecteur WG Theory, 2016).  
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37 422 Stakeholders did not adopt the academic understanding of connectivity, despite one-fifth of  
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39 423 stakeholders having previous work with scientists; and one-third having previous involvement in  
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41 424 projects with ties to connectivity. Areal & Riesgo (2014) demonstrated that perceptions and  
42  
43 425 motivations for management adoption are influenced by neighbouring conditions, which was  
44  
45 426 supported here by Mediterranean region- and Central-European farmers having perceptions of  
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47 427 landscape linkages in line with their own key challenges, which in fact are the underlying  
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49 428 motivation for whether management is adopted.

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51 429 Stakeholders' perceptions of fluxes, water and sediment transfer, and their uneven  
52  
53 430 spatiotemporal distribution were strongly related to the connectivity concept (Connecteur WG  
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55 431 Society, 2016), and thus represented existing background to understand and adopt connectivity  
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57 432 concepts. Application of our proposed connectivity management potential (*CMP*) index allowed



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4 433 us to clearly distinguish stakeholders with different degrees of connectivity management  
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6 434 potential. Despite being unaware of recent developments in connectivity research, two-thirds of  
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8 435 stakeholders managed connectivity related linkages, thus confirming our second hypothesis.  
9  
10 436 Additionally, over 25% of stakeholders found connectivity management an important piece in  
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12 437 successful management decisions. This result is critical for improving knowledge and/or  
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14 438 technology transfer between academics and end-users. Furthermore, we suggest applying the  
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16 439 index proposed herein for simple assessments of stakeholders' connectivity management  
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18 440 potential. Despite, connectivity management potential index should not be exchanged for in-  
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20 441 depth analysis of stakeholders' perception, motivation and management adoption barriers in  
21  
22 442 concrete projects, proposed index might be applied as a part of the analysis. Based on our  
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24 443 results, stakeholders with high connectivity management potential may be more successful  
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26 444 partners resulting from their willingness to apply connectivity-focused management.

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#### 446 *Next steps for moving forward*

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

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4 461 approaches (Fryirs & Brierley, 2016), and sustainable governance (e.g., ecological connectivity  
5 462 -Kininmonth et al., 2015).

6  
7 463 In order to ensure connectivity approaches and tools are transferred to stakeholders, it is  
8  
9 464 necessary to actively engage stakeholders preparing legislation, standards and/or guidelines,  
10  
11 465 as well as policy makers. According to Bouma & Montarella (2016), scientists play a specific  
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13 466 role in linking policy and stakeholders in environmental management issues, but it is first  
14  
15 467 necessary to intervene with the cycle of policy-making. This includes signalling (e.g., identifying  
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17 468 problems, defining goals), through design and decision, to implementation. Such cooperation  
18  
19 469 proved to be effective on multiple scales (Bouma & Montarella, 2016) and should be applied at  
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21 470 international and EU level considering the legislative environment in Europe. This process  
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23 471 would actively engage connectivity scientists in order to prepare new policies (e.g., in  
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25 472 connection to European Commission Soil Thematic Strategy).

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27 474 Conclusion

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31 476 Studying European stakeholders' perception of water and sediment connectivity proved that  
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33 477 both direct and indirect perceptions of connectivity exist among stakeholders involved in water  
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35 478 and land management. Furthermore, the results demonstrated stakeholders' potential and  
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37 479 willingness to manage connectivity more efficiently. It also revealed heterogeneity in  
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39 480 connectivity-related challenges between different groups, but pinpointed that despite being  
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41 481 perceived differently, they are often related or the same issue. These issues were primarily  
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43 482 water quantity, soil erosion, sediment transport, soil and water quality, data and methods  
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45 483 availability, communications, policies and institutions. Increased understanding of connectivity  
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47 484 and its role in management may result from focusing on knowledge transfer within case studies,  
48  
49 485 and from demonstrating connectivity-related issues, methods and tools described from  
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51 486 stakeholders' viewpoint. Improving data availability and cost- and labour-effective tools/models,  
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53 487 together with including stakeholders in common project and development of connectivity  
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55 488 management tools would improve their applications. Additionally, exchange between policy  
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57 489 makers and scientists appears essential for improving or creating successful policies and

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4 490 political instruments applicable to all relevant parties. Such exchange would dissolve or reduce  
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6 491 obstacles that are hindering the potential for linking recent connectivity research developments  
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8 492 to practical application, and enhance the potential for effective management from European  
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10 493 stakeholders in water and land management.

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662 Table 1. Questionnaire given to stakeholders

N	Question	Purpose
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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 – hypotheses 1 and 2 stated in section 2.

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670 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

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687 Table 3. Stakeholders' dataset

<b>1. Country of origin</b>						
	Spain	Bosnia and Herzegovina	Turkey	Portugal	Group 1	Group 2
% of stakeholders*	46	11	6	5	4	1
<b>2. Gender</b>						
	Male	Female	ND			
% of stakeholders	65	15	20			
<b>3. Education by level</b>						
	No tertiary	University	PhD	ND		
% of stakeholders	20	60	14	6		
<b>4. Education by subject</b>						
	Agriculture	Watershed management / Hydrology	Civil Engineering	Physical Geography	Others	ND
% of stakeholders	25	8	8	6	13	40
<b>5. Stakeholder group (type of institution in Table 2)**</b>						
	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			
<b>6. Role in water and land management</b>						
	Implementation of decision	Decision making	Management of individual sector	Combination of previous	Others	
% stakeholders	29	31	13	16	12	
<b>7. Collection of data by stakeholders ***</b>						
	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	
<b>8. Use of spatial information and environmental models ***</b>						
	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

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

Institution	Administration												Total											
	Agricultural				Water & Land				Environmental							Farmers				Others				
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	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 ( $p>0.01$ )

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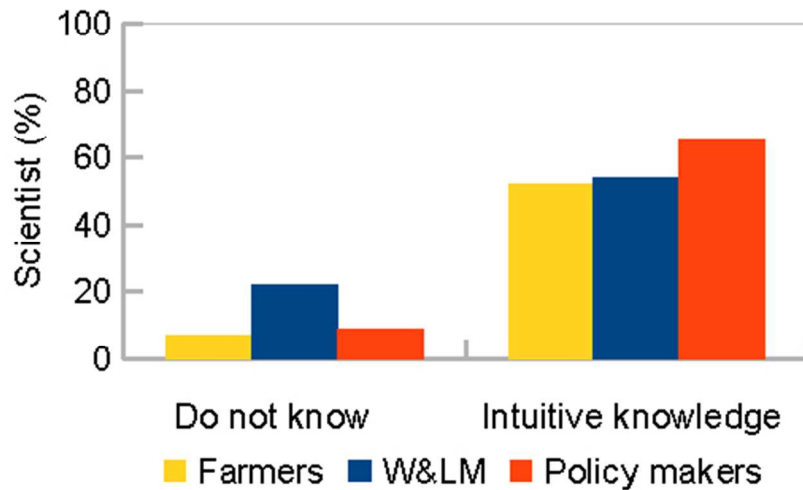


Figure 1. Poll among 46 connectivity scientists about stakeholders' perception (2nd MC Meeting of EU COST Action ES 1306 Connecteur, 16-17/09/2015, Durham, UK). Percent of scientists who answered positively to the following statements is plotted on the Y-axis: 1. (left) "Stakeholders in water and land 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.

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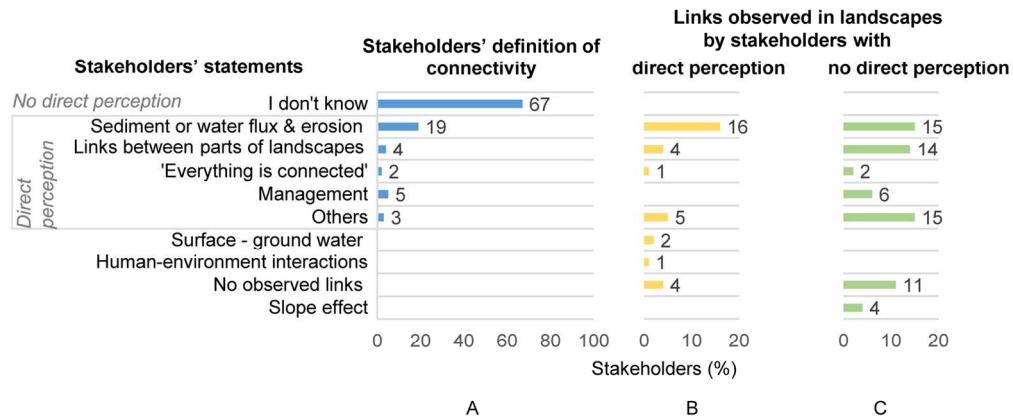


Figure 2. Results from the stakeholder questionnaire summarizing the answers regarding stakeholders' direct (A) and indirect (B, C) perception of water and sediment connectivity. B. Links observed by stakeholders who defined water and sediment connectivity. C. Links observed by stakeholders who did not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

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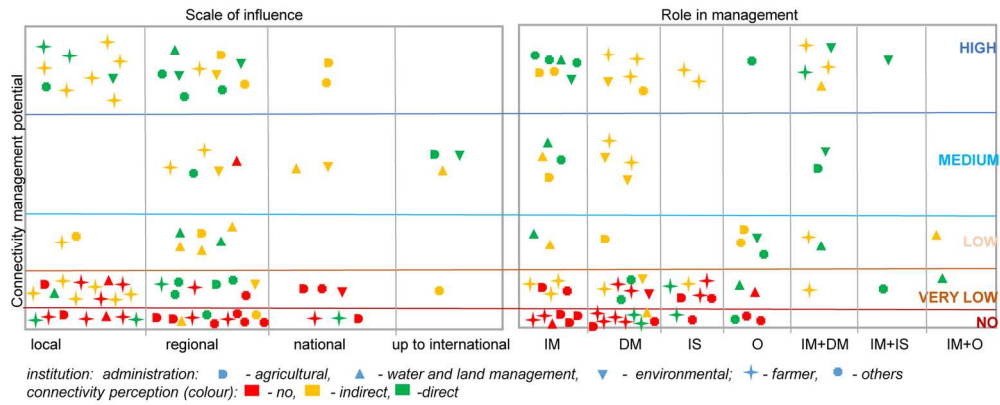


Figure 3. Stakeholders' connectivity management potential, calculated from the answers on stakeholder questionnaires about recognition and management of connectivity related linkages and connectivity. Calculation is based on index of connectivity management potential (eq. 1).

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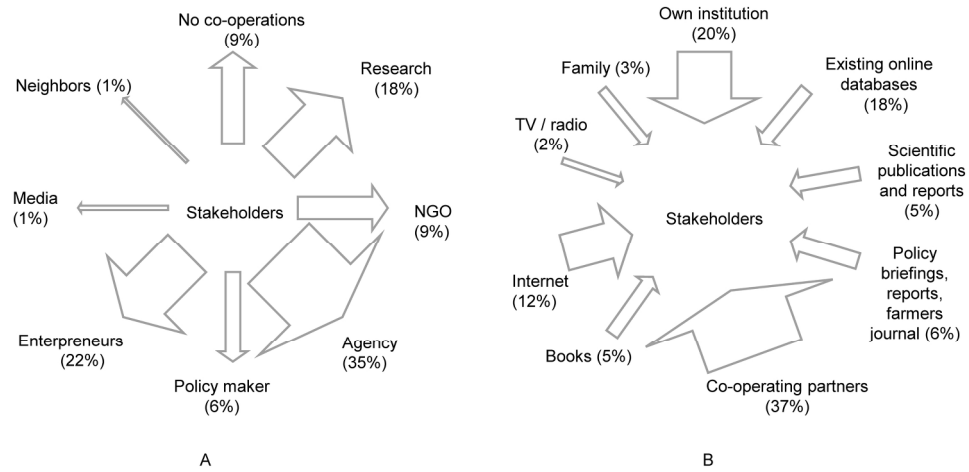


Figure 4. Results from the stakeholder questionnaire summarizing answers about stakeholders' cooperation (A) and information resources (B). The width of arrow is scaled representing indicated percentage.

100x58mm (600 x 600 DPI)