

## ***Interactive comment on “A conceptual framework for assessing socio-hydrological resilience under change” by Feng Mao et al.***

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We thank Dr Wesselink for her thoughtful and reflective comments, providing invaluable insights from the critical social science water research domain. Nonetheless, we think there are also a number of misunderstandings about the purpose of our paper and its positioning for readers of HESS. Consequently, in this reply we clarify our perspective on the ‘problem’, key contributions and approach, as well as setting out changes in response to Dr Wesselink’s commentary. These changes will be incorporated in the revised version of the paper.

Dr Wesselink’s comments address three aspects, which we take in turn in our reply (below). These are: (1) the concept of resilience; (2) ecosystem services, and (3) usefulness of the resilience canvas for policy making.

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### (1) Resilience concept.

The first comment is on the concept/ definition of resilience, one of the cornerstones of the paper. We state that ‘Resilience can be understood as a set of systemic absorptive, adaptive and transformative capacities (Walker et al., 2004, 2009)’. Dr Wesselink states that we have ‘redefined resilience to mean “absorptive, adaptive and transformative capacities”’, and asks us to explain the relationship of these three capacities. She also asks why only the first two ‘capacities’ are covered in the ‘resilience canvas’ discussion.

Resilience is a concept with a long tradition; it has a very wide range of definitions, set out in a variety of disciplinary literatures. Yet as the reviewer notes, our paper’s aim ‘is not to describe this variety’, nor to offer ‘an extensive literature review on resilience’. Rather, we attempt to examine the potential of applying resilience in socio-hydrological contexts. To achieve this, our paper analyses the constitutive elements of both socio-hydrology (water, human and human-water) and resilience.

Given the constraints of the opinion paper format, we identify the most relevant attributes of resilience from the literatures as absorptive, adaptive and transformative capacities, without seeking to re-review the whole range of resilience characteristics (source literatures cited). In fact, resilience and adaptive capacity have very similar characteristics but opaque/ambiguous interrelations, depending on authors’ viewpoints. Examples include:

- Resilience is synonymous with adaptive capacity. Tompkins and Adger (2006) for example argue that ‘Adaptive capacity, which is often used to refer to the set of pre-conditions that enables individuals or groups to respond to climate change [...] is a synonym for many characteristics of resilience.’ (p.5)
- Resilience is a subset of adaptive capacity (e.g. Cutter et al., 2008, Fig. 1; Gallopín, 2006, Fig. 5).

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- Adaptive capacity is a subset of resilience. For example, Carpenter et al (2001) argue that 'adaptive capacity is a component of resilience' (p.766).

Faced with these different formulations, we had to choose a starting point to contextualise the socio-hydrological discussion in the later parts of the paper. To summarise and clarify, in the paper we emphasise the following propositions made already about resilience in the wider literature (source literatures cited).

- Resilience is a set of system capacities (Kuhlicke, 2013; Norris et al., 2008).

- The most salient attribute of resilience is absorptive capacity (Béné et al., 2014; Walker et al., 2004).

- Adaptive capacity is a component of resilience (Carpenter et al., 2001).

- The main difference between adaptive and transformative capacities is their magnitude of change/response. Both adaptive and transformative capacities may change the systems or stability domains, but the latter is a more extreme and sometimes 'revolutionary' form. For example, Béné et al. (2014) argue that 'Eventually, if the changes required are so large that they overwhelm the adaptive capacity of the household, community or (eco)system, transformation will have to happen' (p. 602), adaptive and transformative capacities lead to 'incremental' or 'transformational' changes in response of disturbances (p. 601). Because of their similarity, this is one of the main reasons why only 'adaptive capacity' is mentioned in the 'resilience canvas'. Another key reason to focus upon absorptive and adaptive capacities is that they are more common than the transformative capacity, and a 2D space is much more practical to convey this than a 3D space.

In sum, we reflect the line of argumentation on resilience in mainstream academic debates, rather than seeking to reconsider or re-evaluate the concept itself. Moreover, we are not the first one to identify or utilise these three characteristics: see for example Béné et al., 2014, 2015; Miller et al., 2011; Pelletier et al., 2016. Hence, we believe

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we have positioned the concept of resilience appropriately and added-value for the HESS readership.

(2) Ecosystem services.

Dr Wesselink agrees that 'ecosystem services are clearly another way to look from the human', but then later states that 'ecosystem services are hardly needed in the rest of the paper', and recommends we 'remove it'. We disagree; introducing ecosystem services in the paper and into socio-hydrological resilience debates is essential, for the following reasons.

First is that ecosystem services not only provide a means to 'characterise the resilience of the human-water systems', but more importantly offer a novel perspective from which to view resilience in socio-hydrological contexts, and to stimulate new discussion on this under-researched interrelation. In this way, the theoretical contributions from ecosystem services research can we think nourish the comparatively new research field of socio-hydrological resilience, while the policy-relevant nature of ecosystem services may also prove instructive in clarifying resilience-based decision-making in socio-hydrological contexts. Moreover, this novel perspective flags the potential broader connections between resilience and ecosystem services. That is to say, the paper seeks to open up new areas of inquiry based on this novel synthesis of the two literatures as a basis for further research, rather than offering definitive answers.

In the paper, we argue that 'system identities need defining before examination is undertaken of their intrinsic resilience types' (p. 6), and 'key indicators of system state need to be established' (p. 3). For relatively conventional human-water combinations such as 'Water subsystem with anthropogenic hazards' and 'Human subsystem with hydrological hazards', the system state and its key indicators are straightforward. However, defining the state and indicators of coupled systems (i.e. socio-hydrological systems) is more problematic. The paper addresses this challenge by proposing the use of ecosystem services to describe the dynamics of socio-hydrological systems. Re-

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moving reference to ecosystem services would therefore compromise the argument set out in the paper.

Furthermore, we use ecosystem services to consider the pathways to resilience in Section 4. So we argue ‘Susceptible socio-hydrological systems can be strengthened [...] by making hydrological ecosystem services supply more robust and sustainable under current hazard regimes’ (p.9 line 19). We argue that managing the supply of ‘hydrological ecosystem services’ is the key to improving susceptible socio-hydrological systems, instead of managing other indicators such as hydrological biodiversity, naturalness, social security, integrity or justice. Without prior discussion of ecosystem services in advance, it would be difficult to describe what needs to be achieved in a resilient socio-hydrological system. Thus, we are clear that introducing ecosystem services and connections to socio-hydrological resilience debates is essential to communicate our key research contributions.

(3) Usefulness of the ‘resilience canvas’ for policy making.

Dr Wesselink comments on the usefulness of the ‘resilience canvas’ for policy making, and asks how to connect socio-hydrological resilience as a boundary concept with targets, how the targets can be determined, who set the targets, and how to engage policy process with resilience.

We fully agree that resilience is a ‘boundary object’, is ‘classified as wicked or unstructured problem’, and is difficult to apply in practice in public policymaking. Indeed, it was precisely to grapple with this difficulty that we wrote the paper. We believe that the main contributions we make to this significant challenge are:

- Two/three dimensional features of resilience capacities. This helps to make the concept of resilience more specific for policy making. For example, ‘improvement of the absorptive capacity’ is to ‘resist existing hydro-hazards’, while enhancing adaptive and transformative capacities are to ‘cope with future uncertainties’, incrementally or radically (p.8).

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- Potential linkage between socio-hydrological resilience and ecosystem services. As explained in the previous paragraphs in this response, the concept of ecosystem services injects further policy-relevance into resilience debates. Introducing ecosystem services into socio-hydrological resilience discussion offers, we argue, a means of engaging resilience thinking with future ecosystem services-based policies.

- As Dr Wesselink notes, we foreground the role of ‘people’ in deciding resilience goals. Besides the two quotes highlighted by the reviewer (p.7 line 1 and p.13 line 9), we also state ‘... using ecosystem services to measure the state of socio-hydrological systems not only reflects the “naturalness” of the hydrological system, but also human preferences for the resulting coupled system. So, a continuing supply of ecosystem services does not necessarily mean ecosystems are pristine or close to a “natural” condition, but instead reflects the preference of the human subsystem to select for particular services’ (p.8 line 2). It goes without saying that expectations of what resilience is will differ among stakeholders; this is a given of all aspects of environmental social science, and finding new ways to address how this variability can be reflected within the policy process is of paramount concern. But again, our aim here is not to discuss these normative aspects. We flag one way forward on p.12 line 4, in stating that ‘polycentric water governance and public participation in more centralised forms of decision-making may play important roles in building socio-hydrological resilience’. In the revised version, we will make this point more explicit and more substantive.

Dr Wesselink finds ‘the discussion in Section 4.2 too general and too obvious’. We will work on this section to make the description more specific in the revision. However, again we reiterate that our main focus in this opinion paper is not to advocate definitive answers for building or enhancing resilience, but instead to demonstrate how such studies can be placed on stronger foundations by classifying and mapping resilience-based strategies through the concept of the resilience canvas.

Dr Wesselink points out that not ‘everywhere the current pathway can be described as “people and water”’. Again, we concur, though there are a couple of issues to clarify

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here. We do not describe the current pathway as ‘people and water’. Instead, on p.10, we introduce the three stages as ‘development phases of global human-water relations’ by reviewing existing research, and state that ‘most current water management practice is now seeking to transition from resistant to resilient strategies’ (p.11 line 28). This should not however be construed as meaning that everywhere in the world at every scale is at exactly the same stage; the picture is of course far more spatially and temporally differentiated. Furthermore, as we note the ‘resilience canvas’ is ‘a heuristic tool to design bespoke pathways to resilience’ (p.9 line 16) rather than a prescribed normative ‘answer’ to issues arising within a current stage.

To address the above issues in full, we will make a number of alterations to the manuscript as detailed below.

- In Section 2, we will further explain why the three resilience attributes (absorptive, adaptive and transformative capacities) are selected and what their interrelationships are.
- We will enrich and expand Section 3.1 and 3.2 to make the idea of resilience in socio-hydrological context more explicit.
- We thank the reviewer for her suggestion to remove the word ‘sustainable’ in p.11 line 25 to restrict the discussion within the field of resilience and to avoid confusion, and will do so in the revised manuscript.
- In the revised version of the paper, we will strengthen the reasoning behind why ecosystem services are needed in the argument, especially in Section 3.
- We will improve the discussion in Section 4.2, and make it more specific.
- We will clarify and flag the importance of water governance issues (e.g. who participate, who set the goals, and how stakeholders are engaged), especially in Section 4.
- We appreciate the suggested references, and will use them where appropriate.

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