Dear Professor Savenije,

Thank you very much for your insightful comments on our manuscript. We would like to take this opportunity to address your comments by clarifying those points that were not clear in our manuscript and proposing how we will improve our manuscript based on your comments.

I do understand that this is a data-mining exercise, and that the authors did not necessarily familiarize themselves with the field of Water Resources Management and its development over time. I recommend looking at the paper on "Evolving water science in the anthropocene" (https://hess.copernicus.org/articles/18/319/2014/) and the huge body of papers that have recently been published under the IAHS research initiative "Panta Rhei", e.g. "Global perspectives on hydrology, society and change", Hydrological Sciences Journal, 61:7, 1174-1191, (DOI:10.1080/02626667.2016.1159308).

Thank you very much for your comments. We will revise our introduction section by making our motivation and approach clearer as briefly discussed below.

Our motivation

Humans have made substantial impacts on various Earth system cycles, marking the transition of our planet into the Anthropocene (Crutzen, 2002; Crutzen & Stoermer, 2000). This has been powered by developments of science and technology in particular since the Industrial and Scientific Revolutions (Lewis & Maslin, 2015; Lubell & Morrison, 2021; Steffen et al., 2011). Rethinking scientific development in the Anthropocene is crucial for our future survival. Hydrological cycles are a central component of the Earth system and it is widely recognized that the stationarity of hydrological systems is dead as a result of human activities (Ajami et al., 2017; Birkinshaw et al., 2014; Milly et al., 2008). Therefore, to **investigate the knowledge gap of hydrology/water resources from its evolutionary history could increase our capacities adaptive to transition into the Anthropocene**.

Our approach

The hydrology/water resources knowledge is a complex disciplinary system and a sub-system of the entire knowledge system covering all scientific disciplines. It is recognised that the functionality of a complex system depends on its structure (Huttenhower et al., 2012; Sayles & Baggio, 2017; Von Bertalanffy, 1968). The disciplinary knowledge structure is often analysed in two primary ways. First, discipline experts qualitatively review and assess theoretical advances, technology (methods and instruments) development and key challenges in the field based on their research experiences and professional knowledge (e.g. McMillan et al., 2016; Savenije et al., 2014; Sivapalan, 2018). Second, systematic bibliometric studies are conducted to quantitatively survey the structure of disciplinary knowledge and reveal the interactions among major research topics (e.g. Zare et al., 2017; Zeng et al., 2017). This paper aims to investigate the hydrology/water resources knowledge structure development using the complex network system approach on bibliometric data **to complement to those findings from existing professional knowledge and research experience and identify the potential gaps of knowledge structures of major river basins in the world.**

Specifically, we will examine the development of hydrology/water resources knowledge structure on:

- Evolution of management issues (study objects) by temporal stages;
- Evolution of the disciplinary structure by temporal stages;
- Links between the disciplinary structure and the management issues; and
- Collaborations of hydrology/water resources disciplines with other disciplines.

In addition, we will also use these recommended references along with others to discuss the implications of our findings from the perspective of complement to existing findings of professional knowledge and research experience in a later paragraph related to the Discussion section.

The authors have analysed papers categorised in the WoS under Water Resources and limited the analysis to articles that deal with river basins or catchments in a broad sense. They then looked for connections between disciplinary fields of WRM and analysed the connections between these fields and *how they developed over time. They then classified the patterns of interconnection, or lack thereof into knowledge structures with the following names: Isolated, Innovative-inclined, Legacy-inclined and Centralised. To me, these classifications have hardly any explanatory power. I have gone through the description several times, but I fail to see what these terms actually mean or imply in relation to WRM. I can't see whether they have a positive or negative connotation. To me, Isolated and Centralised sounds rather negative; Innovative-inclined sounds positive; and Legacy-inclined may be both positive or negative, depending on one's perspective. That in recent years more basin studies are legacy-inclined may be evidenced by the data, but I have difficulty to see what it means.*

Thank you for your comments. We will revise our data and methods section to further clarify the knowledge structure metrics and their significances as briefly discussed below.

To clarify the significance of different knowledge structures to river basin management practices, **we will reorganise our classification of knowledge structure into four types using the two commonly used metrics in the system network theory: centrality and diversity.** Centrality measures the number of connection a node has in a knowledge network system, reflecting the level of knowledge concentration: the greater the centrality, the more connected a discipline is and thus more concentrated. Diversity measures the inverse sum of connecting distances to all other nodes, reflecting the extent to which a node is isolated within the knowledge system: the greater the diversity, the fewer extended connections a discipline has and thus forming more confined small groups in the network. Empirical analyses have demonstrated that concentrated knowledge structures facilitate dissemination of existing knowledge, whereas isolated structure can increase adaptivity to different disciplinary knowledge and facilitate radical innovations to knowledge development through looking from divergent angles (Bodin & Prell, 2011; Foray, 2018; Schot & Geels, 2008).

Based on the differences between the centrality and diversity values, four types of knowledge structures can be identified (Figure 1). They are:

1. Ideal structure with high centrality and high diversity. With this structure, the river basin should have high research intensities in core disciplines to provide solid theoretical foundations, while at the same time sufficient cross-disciplinary collaborations to ensure knowledge innovations to address unexpected, emerging river basin management challenges.
2. Innovation-inclined structure with high diversity but low centrality, which could have a risk of discipline hollowing-out (marginalization of influence of core discipline). For the river basins with this structure, the connection with core disciplines (centrality) should be strengthened.
3. Legacy-driven structure with high centrality and low diversity, which discourages knowledge innovation. In the river basin with this structure, the cross-disciplinary collaborations (diversity) should be strengthened to increase the potential of knowledge pattern transformation against emerging management challenges; and
4. Underdeveloped structure with low centrality and low diversity, indicating that the knowledge development is still at its early stage and the knowledge development should be strengthened comprehensively.

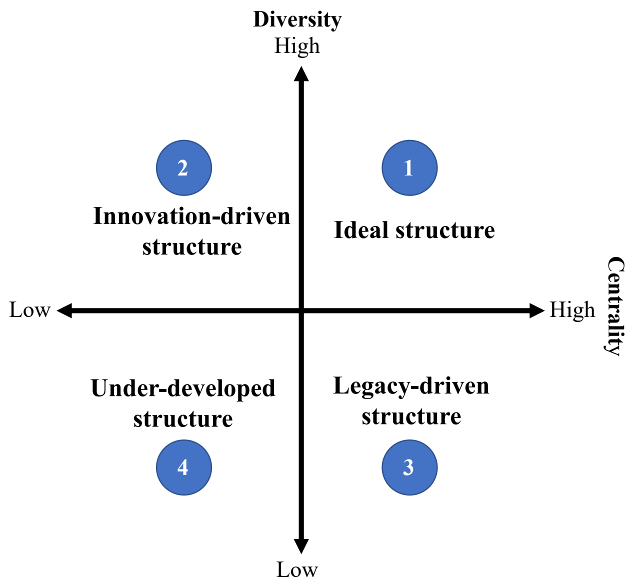

Figure 1 Four different knowledge structures based on their structural metrics

Therefore, **classifying the knowledge structure of the river basins into four different knowledge structural types enables direction of the strategic design and planning of future research from the structural perspective.**

By choosing to analyse traditional disciplinary fields, such as: Agricultural irrigation; Erosion and sedimentation; Water pollution and treatment; Surface water and groundwater management; Ecological degradation; Droughts and floods; Climate variability and change; the results obtained are hardly pointing towards stronger societal linkages. I miss emerging new fields, such as: demand management; decentralisation; participation; international water law; .... and new technologies such as Remote Sensing, New observation technology, Global modelling, Artificial intelligence, ... If you look for traditional terms, you are bound to find traditional results.

Thank you for your comments. To clarify, the nine topics we identified were derived from our data rather than pre-set. To comprehensively reflect the management issues in our methods section, we have extracted key words from the sections of Title, Abstract and Keywords rather than only the Keywords section of each publication using text-mining techniques. These key words were extracted if they have high weighting values on their Term Frequency-Inverse Document Frequency (TF-IDF). TF-IDF was calculated to give higher weights to key words with a high appearance frequency in its corresponding section and a low overall appearance frequency in the entire text collection to avoid a bias towards general terms and grasp the newly appeared key words.

In addition, **we will re-examine and highlight those newly appeared key words in each temporal stage and may categorise them in newly defined groups to more precisely reflect the evolution of management issues.**

By taking river basins as the entree point, I fear the authors have missed a huge body of conceptual and global research. Not all WR research is done at river basin level. Much happens at the global scale, national scale, policy scale or conceptually.

We chose river basin as the spatial unit for analysis as it represents the territorial unit of water cycle linking to other cycles of the Earth system (e.g. nutrients, energy, and carbon), which are commonly adopted by researchers to understand the integrated impacts of water use, land use and environmental management (Newson, 2008; Warner et al., 2008). We merged those publications focusing smaller spatial units (e. g. sub-catchment, or wetland or lake into the river basin which they are affiliated with). **But we agree that we may have missed the publications on general conceptual/theoretical development without specific spatial links and those publications at global scale. Thus, we will revise our manuscript title as "Gaps of knowledge structure in river basins".**

Part of results will be revised based on the change of methods as discussed above.

Section 4. Discussion and Conclusion, is hardly a discussion. It is rather a set of three recommendations where certain lines of research are "encouraged": 1) investigation of "new" river basin phenomena; 2) spatial diversity of Water Resources research; and 3) strengthening collaborations with social sciences. These are rather obvious and general recommendations and hardly a discussion. The conclusion that "the stationarity of the water resources knowledge system persist" is not supported by the large body of work that is recently being produced as a result of and as part of the "Panta Rhei" initiative. This large body of work is hard to detect if one constrains oneself to the 95 most studied river basins in the world and the connections to traditional fields.

Thank you for your comments. We will revise our three recommendations based on the results to be updated and draw the conclusion from **the perspective of knowledge structure** of river basin.

We will discuss the implications of the key findings from the following aspects:

1. **We will discuss the implications of our findings from the perspective of complement to existing findings of professional knowledge and research experience.** This will be done by briefly summarizing the evolution of management issues and discipline of hydrology/water resources knowledge structure by reviewing the key findings from the IAHS Scientific Decades since its foundations in particular the most current "Panta Rhei" Decade, covering the studies you recommended and major review articles published in the Water Resource Research, HESS and other hydrological journals.
2. **We will discuss the intrinsic cause of current knowledge structure by briefly discussing the challenges in integrating hydrology with social sciences from the epistemological, ontological, and political perspectives,.**
3. **We will discuss the extrinsic cause of current knowledge structure from current academic capitalism; and**
4. **Finally, we will discuss the limitations of our study including only journal papers were considered and focusing on river basin scale studies.**

Once again, thank you very much for your valuable comments.

Your sincerely,

The authors team:
Shuanglei Wu; Yongping Wei; Xuemei Wang.

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