Catchment Resilience

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Catchment resilience can be used as a unifying concept to explore the role of latent conditions that are triggered by hydro-hazards and their impact on exposed people or assets. Catchment resilience requires acknowledging the interactions between natural, technical, and social systems within a catchment, and considering feedbacks between exposure, vulnerability, and resilience of the catchment.

resilience complex systems catchment

1. Introduction

Catchments must be considered as complex adaptive systems comprising interrelated natural, social and technical systems; and resilience must be considered a fluid concept to acknowledge the context in which it is being applied. For catchment resilience, we must consider a shock occurring within a catchment, e.g., a flood or a drought (hydrohazard [1]), and we must recognise that these shocks are not stationary, i.e., the influence of climate change is modifying the frequency, magnitude and duration of these shocks [2][3]. The tripartite resilience concept [4][4] alludes to some key considerations in applying this theoretical systems thinking to actually grappling with resilience in the real world.

To consider resilience in these complex systems, we need to move towards a complex adaptive systems approach which recognises the systems' ability to transform in the face of a shock (hydrohazard). Due to their nature as complex adaptive systems, catchments are under constant reorganisation, and evaluative measures will need to be applied in an ongoing fashion to account for this changing context. Consequently, we undertook a structured review of the state of the art methods which deal with adaptation within catchments.

2. Complexity Challenges for Catchment Resilience

In order to inform our review of the state of the art in systems research within climate change adaptation [1], we identified six complexity challenges [1]; these challenges apply directly to the assessment of catchment resilience. These six challenges are informed by key literature in complexity, sustainability, and transformations [1][5][6][7][8], frame the critical considerations to be addressed in this section, and include:

- Natural-social-technical aspects: Acknowledging and accounting for the influence and feedback arising from human values, behaviour, culture, infrastructure and institutions;

- Interactions: Accounting for multiple interactions across natural, social, and technical systems; connecting global-scale dynamics to local realities and vice versa;
- Spatial scales: Coverage of multiple spatial scales; connecting contextual, place-based understandings (bottom-up) with theoretical and systemic knowledge (top-down);
- Time scales: Coverage of multiple temporal scales;
- Multiple forms of evidence; and
- Uncertainty: Recognitions of the uncertainty in future projections.

Using the six complexity concepts identified, we recently reviewed 910 papers on climate change adaptation to hydrohazards [1] in a structured manner. These papers were analysed to understand the degree to which they incorporated the six complexity concepts, and which methods were used to do so. Straightaway, 173 (19%) of these papers addressed none of the six complexity concepts, even in a cursory search for these concepts within titles, abstracts and keywords. From this, it is clear that the journey to truly 'doing systems research' has just begun.

At the forefront of operationalising these initial two concepts (natural-social-technical subsystems, and their interactions) is the need to address different spatial and temporal scales. McClymont et al. [4] found that few existing studies adopt a systems-thinking perspective which allows all interactions to be taken into account across multiple spatial scales by focusing on interrelationships and feedback loops. When this is performed, it is typically with heavy emphasis on social aspects (e.g., [9][10]). Only rarely do papers attempt to combine the social and technical interactions across different spatial scales for a more holistic understanding of catchment resilience (e.g., [11][12]).

In our structured review [1], we found that most studies tended to focus on assessing medium-term time-scale impacts (i.e., taking months or years [13][14][15]), without strong connections to the study of short-term time scales (i.e., taking hours, days, or weeks). The full database of studies on climate change adaptation to hydrohazards is available for reference [16]. This focus on the medium term is somewhat expected because the impacts of a hazard, such as a flood or drought, can take more than hours, days, or weeks to be fully realised, for example, the impacts of a flood on a city's wider health care system. However, without a robust understanding of how short-term dynamics lead to medium- or long-term effects (e.g., stressors) being realised, it will be difficult to create effective interventions and transformative adaptation. We also found [1] that the medium-term time-scale studies are significantly correlated to the study of ecological, economic, and social impacts [14][15]. Economic and social impacts are currently studied in a primarily top-down fashion (e.g., using census data), which could be a barrier to the unpicking of system dynamics and interactions. A challenge in this area is that the study of interactions at multiple time scales is an inherently data-intensive exercise, so it is often only performed in the short-term time scale, to minimise data requirements. Emphasis is needed on methodological development to study interactions in general, but particularly in linking the short- to medium-term time scales, and ideally in a way that minimises data requirements.

Interlinked with the consideration of multiple spatial and temporal scales is the need to connect ‘top-down’ (from a large and broad spatial scale, e.g., prescribed by institutions at the national level) and ‘bottom-up’ (from a local context, e.g., agreed and proposed by the neighbourhood or community scale) solutions. These two approaches also typically require different forms of evidence and models. Bottom-up approaches are considered to be the most relevant to resilience, particularly in understanding the interplay of institutions, flood risk communication, and flood modelling tools [17]. However, results from our methods review [1] show that ‘bottom-up’ data are often physical or natural (e.g., rainfall measurement), and are often only integrated with ‘top-down’ social data (e.g., census datasets, indicators) [18]. Often when participatory methods (e.g., focus groups) are used, these are combined only with qualitative data collection (e.g., survey) and corresponding statistical analysis. Thus, when multimethod, multiscale approaches are used, these are often top-down decision-making tools with quantitative analysis [19]. These approaches continue to be extremely data and time intensive, requiring multiple sophisticated models. What is missing—and what could arguably alleviate the data hunger of higher-level policy- and decision-making analyses—is the ‘end user’ and their insights into local context. To fulfil the recommendation of O’Sulliven et al. [17], we must seek fuller integration of ‘bottom-up’ social methods (e.g., participatory), with higher level policy and practice processes, to inform more effective and equitable outcomes. This suggests a move away from exclusively top-down, technocratic approaches. Indeed, the allowance of small manageable floods enables community adjustment and learning over time, increasing resilience capacity to cope with larger, unpredictable flood events [12][20][21]. However, care should be taken in balancing bottom-up and top-down approaches. Consideration of the collective, distributed responsibilities for catchment resilience is needed, as rescaling of resilience to be the exclusive responsibility of the community or household level risks neglect of the state’s accountability [22]. Rather than “failure becom[ing] a property of those who fall victim” [22] p. 1083, each catchment should collectively consider how to distribute responsibility for its resilience amongst government, regulatory, and community organisations based on local context, to ensure an equitable and ultimately more effective strategy for resilience.

Finally, uncertainty—particularly surrounding the natural hazards we might expect in the future—is a key consideration. To address climate change adaptation to hydrohazards effectively within the concept of catchment resilience, it will become increasingly important to address both ends of the hydrological spectrum in a comprehensive way [3][23][24][25]. While floods and droughts are covered equally overall, floods and droughts are considered together only in approximately 23% of cases. In other words, consideration of the entire hydrological cycle is essential, possible, and often unaddressed. The inverse of this finding is the possibility that approaches capturing interactions and using multiple forms of evidence have greater potential to be extended across hazard types (i.e., from application of floods to application of forest fires). Thus, a high priority for future catchment resilience research is to develop and apply methods which are in some ways ‘hazard agnostic’ in their capability to consider not just floods and droughts together, but any combination of multiple, interacting, or compound hazards.

In general, this might also include the characterisation of latent social or technical vulnerabilities as dormant hazards.

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