




Research, part of a Special Feature on [Panarchy: the Metaphor, the Theory, the Challenges, and the Road Ahead](#)

# Inequalities in the adaptive cycle: reorganizing after disasters in an unequal world

[Marie C. Dade](#)<sup>1,2</sup> , [Andrea S. Downing](#)<sup>3,4</sup>, [Karina Benessaiah](#)<sup>5,6</sup>, [Marianne Falardeau](#)<sup>7,8,9,10</sup>, [Mi Lin](#)<sup>5,11</sup>, [Jesse T. Rieb](#)<sup>1</sup> and [Juan C. Rocha](#)<sup>3,12,13</sup>

**ABSTRACT.** Natural hazards can trigger disasters that lead to the collapse and reorganization of social-ecological systems. This reorganization can involve systems transitioning to more positive trajectories. The Panarchy framework, which conceptualizes social-ecological systems as dynamic interrelated adaptive cycles, is a common conceptual framework for understanding system reorganization. However, it is unclear how inequalities, social mechanisms known to influence disaster recovery outcomes, shape a system's adaptive cycle post-disaster. Understanding the roles of inequalities can help develop social-ecological models to identify processes that build resilience into disaster recovery. We applied the Panarchy framework to inform propositions describing how inequalities can influence the reorganization of social-ecological systems after disasters triggered by natural hazards. We qualitatively analyzed a selection of case studies that discussed inequalities pre- and post-disasters and related these to adaptive-cycle system characteristics (i.e., potential, connectedness, and resilience). We identified three propositions: 1) The ability of groups to reorganize after a disaster varies across the inequality spectrum; 2) The reorganizing abilities of groups across the inequality spectrum impact one another; and 3) The presence of inequalities affect connectedness within the system. Incorporating these propositions into social-ecological system modeling can improve our understanding of how inequalities impact system reorganization. This information can support disaster recovery plans that strengthen a system's ability to enter a more positive trajectory post-disaster.

**Key Words:** *inequality; modeling; natural hazards; panarchy; resilience; social-ecological systems; transformations*

## INTRODUCTION

When natural hazards - such as cyclones, droughts, and earthquakes - occur within social-ecological systems they can trigger disasters, including catastrophic fatalities and declines in social welfare (Pelling and Uitto 2011, Toya and Skidmore 2007). However, disasters triggered by natural hazards, hence forward known as disasters, can also help restructure institutions that reorganize social-ecological systems into new states, where well-being within the system is improved (Cradock-Henry et al. 2018, Brundiers and Eakin 2018, McSweeney and Coomes 2011). Increasingly, there is recognition that social-ecological modeling can help us better understand how and why social-ecological systems may transition to more desirable states after disasters (Schlüter et al. 2019). However, to do this first requires identifying a social-ecological systems framework that captures the full range of mechanisms at play that influence how the system responds post-disaster.

One such mechanism recognized within the social science and natural hazards literature as important to social-ecological system reorganization post-disaster is social inequality. Inequalities occur when resources (e.g., income or social power) are unevenly distributed within the system (Leach et al. 2018). Inequalities influence the social vulnerability of groups to disasters, affecting their ability to respond, cope, and recover, as well as their ability to participate in recovery planning (Islam and Winkel 2017,

Blaikie et al. 2005, Cutter and Finch 2008). Although there is a plethora of information on how inequalities affect individual groups' recovery from disasters, inequalities are still often not considered in many social-ecological frameworks that can be used to model how social-ecological systems reorganize post-disaster.

Many frameworks used to understand how social-ecological systems reorganize after disasters are based on resilience theory. Resilience is defined as the ability of social-ecological systems to absorb shocks, recover, and reorganize (Cretney 2014, Walker et al. 2004). Resilience theory has its roots in ecology, therefore, frameworks developed to understand how social-ecological systems respond to disasters, and the social-ecological models based on these frameworks, often overlook institutional and social mechanisms at play, such as inequality (Cote and Nightingale 2012, Fabinyi et al. 2014).

This is particularly evident in the Panarchy framework (from hereon Panarchy) - a commonly used framework for social-ecological modeling. Panarchy describes the organization and dynamics of social-ecological systems across space and time (Gunderson and Holling 2001). Within Panarchy, social-ecological systems undergo changes through a sequence of growth, accumulation, restructure, and renewal phases in response to external shocks referred to as the adaptive cycle (Gunderson and Holling 2001). Disasters can act as a shock,

<sup>1</sup>Department of Geography, McGill University, Montreal, Quebec, Canada, <sup>2</sup>School of Ecosystem and Forest Sciences, University of Melbourne, Burnley, Victoria, Australia, <sup>3</sup>Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden, <sup>4</sup>Global Economic Dynamics and the Biosphere, Royal Swedish Academy of Sciences, Stockholm, Sweden, <sup>5</sup>Department of Natural Resource Sciences, McGill University, Ste-Anne-de-Bellevue, Quebec, Canada, <sup>6</sup>Department of Geography, Environment & Geomatics, University of Guelph, Guelph, Ontario, Canada, <sup>7</sup>Institute of Integrative Biology and Systems, Université Laval, Quebec City, Quebec, Canada, <sup>8</sup>Department of Social and Preventive Medicine, Université Laval, Quebec City, Quebec, Canada, <sup>9</sup>Department of Biology, Université Laval, Quebec City, Quebec, Canada, <sup>10</sup>CHU de Québec-Université Laval Research Center, Université Laval, Quebec City, Quebec, Canada, <sup>11</sup>Future Earth Montreal Hub, Montreal, Quebec, Canada, <sup>12</sup>Future Earth, c/o Royal Swedish Academy of Sciences, Stockholm, Sweden, <sup>13</sup>South American Institute for Resilience and Sustainability Studies, Maldonado, Uruguay

where a system unexpectedly experiences a sudden release of accumulated resources, allowing the social-ecological system to reorganize into a new state (Geobey and McGowan 2019, Gunderson 2010). While the role and characteristics of disturbances in triggering system reorganizations have been studied and modeled using Panarchy (e.g., Schoon and Cox 2012), social mechanisms, such as inequalities, are rarely considered. Indeed, within Panarchy, societies are generally regarded as homogenous, creating mismatches between realities of unequal outcomes of disasters and the framing of these disasters as opportunities for building equality (c.f. Walker et al. 2020). The roles of inequalities that represent different vulnerabilities to disasters are not yet included in Panarchy, and it remains unclear how to integrate them into the adaptive cycle.

Not capturing inequality mechanisms within Panarchy risks developing social-ecological system models that, if used to inform disaster resilience or recovery planning, may lead to more unequal systems after the disaster. In this study, we aim to explore how to integrate inequality mechanisms into the adaptive cycle to better understand how social-ecological systems reorganize after a disaster. To do this, we first review the conceptual background underpinning Panarchy and inequality research. Using this information, we analyzed a selection of case studies that explicitly discuss inequalities within a social-ecological system before and after a disaster occurred and explore within each case study the inequalities present and the characteristics of the systems' adaptive cycles. From this exercise, we posit a list of propositions describing how inequalities can affect post-disaster reorganization of social-ecological systems and the implications for social-ecological modeling.

## CONCEPTUAL FRAMEWORK

### The Panarchy framework

The adaptive cycle is central to Panarchy and consists of four phases (Holling 1986, Sundstrom and Allen 2019): a) the exploitation phase, where the system has low resources; b) the conservation phase, where the system accumulates resources; c) the release phase, where resources accumulated in the conservation phase are released in response to a shock to the system; and d) the reorganization phase, where the system has the opportunity to develop novel ways to recover and move into a new exploitation phase (Holling 2001). These cyclic phases can be observed in a wide range of systems from business cycles in society to disease outbreaks in ecosystems. For example, in an agricultural system, the exploitation and conservation phases occur when initial crops are planted, then management becomes increasingly intensive to increase crop yield (Winkel et al. 2016). The release and reorganization phases may be triggered by erosion, opening space for new management regimes or crops to be introduced.

The movement of a social-ecological system through these adaptive-cycle phases involves changes in the levels of three main system variables: potential, connectedness, and resilience (Table 1). Potential refers to the accumulated resources within the system, such as social or economic capital (Gotts 2007). Connectedness refers to the strength of internal connections within the system that regulate the influences between internal and external processes (Gunderson and Holling 2001). Resilience

refers to the capacity of the system to absorb shocks, recover, and reorganize (Cretney 2014).

Whether a disaster triggers the release phase of the adaptive cycle, leading to a transition, depends on the characteristics of both the disaster and the social-ecological system (Schoon and Cox 2012). The disaster must be large enough in extent and impact to release accumulated resources and shift the system into the reorganization phase of the adaptive cycle (Brundiers and Eakin 2018, Gunderson 2010). Within the social-ecological system, the resilience, connectedness, and potential present will determine whether the disaster will trigger a transformation or not (Thomalla et al. 2018). This transformation can be institutional changes leading to a more positive state, such as the reorganization of Christchurch's urban design post-earthquake, creating a more sustainable city (Saunders and Becker 2015). In some instances, a social-ecological system can become trapped (Table 1) where, even after a phase of growth, disasters fail to trigger a transformation (Carpenter and Brock, 2008). Even though inequalities are often described as barriers to the transformation of social-ecological systems (Fernández et al. 2016), research articulating how inequalities interact with system variables within the adaptive cycle, and how this impacts the ability of the system to move into the reorganization phase, is scarce.

### Inequalities

Inequalities represent differences in the distribution of resources, opportunities, costs, or benefits among groups of people within society (ISSC et al. 2016). Within social-ecological systems, inequalities can encompass both distinct and intersecting economic, political, social, cultural, environmental, spatial, and knowledge-based dimensions that are context specific (Leach 2018, ISSC et al. 2016). Furthermore, changes in one dimension might trigger changes in another. For example, a person of low income and within an ethnically marginalized group may have a different distribution of resources than someone with a low income but who is not from an ethnically marginalized group (Leap 2018). For any given inequality, population(s) will benefit, or not, to varying degrees based on these intersecting dimensions, with some groups more advantaged by the presence of inequality within society, and others disadvantaged. While numerous studies have explored the impact of inequalities on disaster vulnerability (e.g., Islam and Winkel 2017, Cutter and Finch 2007), how inequalities affect the mechanisms underpinning the ability for social-ecological systems to transform post-disaster remains unclear (Fabinyi et al. 2014), but this knowledge is crucial for developing models that can improve disaster resilience and planning.

There is no best way to quantify inequality, though numerous metrics have been proposed (Cowell 2011). Despite differences in these metrics, social-ecological systems where severe inequalities are present will tend to have 1) a greater difference between the resources available for the more advantaged groups and disadvantaged groups, and 2) the majority of the resource will be disproportionately held by a smaller group. Under these conditions, inequalities tend to be reinforcing, where more advantaged groups maintain advantages - such as through market concentration - often at the cost of disadvantaged groups (Hamann et al. 2018).

**Table 1.** The phases and traps within the adaptive cycle that a social-ecological system may experience, and the state of their corresponding system characteristics (potential, connectedness and resilience) (Gunderson and Holling 2002, Carpenter and Brock 2008).

Adaptive cycle phases and traps	Description	Potential	Connectedness	Resilience
Exploitation	Early successional system / system has low levels of capital.	Low	Low	High
Conservation	Late successional system / system accumulates resources and capital.	High	High	Low
Release	The system's resources and capital are released in response to a shock to the system.	Low	High	Low
Reorganization	The system has the opportunity to develop novel ways to recover and move into a new exploitation phase.	High	Low	High
Rigidity trap	A wealthy, tightly regulated, and resilient system where any novelty is stifled (e.g., a corrupt political system).	High	High	High
Poverty trap	A system where potential and diversity have been eradicated due to misuse or external force. The system has low resilience and is unable to accumulate capital (e.g., overfishing).	Low	Low	Low

There are factors that influence social mechanisms, besides inequality, that influence how a system moves through the adaptive-cycle phases, such as social justice (Cook and Hegtvad 1983, Fabinyi et al. 2014, Cinner and Barnes 2019). We focused specifically on inequality, as its role within the adaptive cycle remains understudied, but it is an important mechanism to consider in social-ecological models. Specifically, understanding roles of inequalities in the face of disasters, which are becoming more frequent due to climate change and environmental degradation, is a key research question in social-ecological resilience research (Hamann et al. 2018).

## METHODS

We gathered a selection of case studies of systems that have experienced disasters triggered by natural hazards and identified the inequalities present and the characteristics of the systems' adaptive cycles pre- and post-disaster. With this information, we identified how inequalities impacted each system's ability to reorganize after the disaster. To gather case studies, in May 2020, we searched peer-reviewed articles using the Web of Science database (search string: TS = ((natural disaster\*) AND (inequalit\*))) and the Scopus database (search string: TITLE-ABS-KEY ((natural AND disaster\*) AND (inequalit\*))). As our aim was not to conduct a systematic literature review, our search strings were not designed to be exhaustive but instead capture a selection of case studies that were comparable but also contained a diverse range of contexts, inequalities, and disasters. We also used "natural disaster" in our search string, though often regarded as a problematic term as it ignores the social dynamics of disasters. However, this term remains widely used to describe disasters triggered by natural hazards (Chmutina and von Meding 2019) and allowed us to gather a selection of case studies that was comparable but also diverse in both publication date, discipline, and context. We limited the search to include only articles written in English (N = 254). We then carried out a two-step screening process to select the final case studies. Firstly, the authors (MD, ML, MF, KB) screened each title and abstract, removing reviews or theoretical papers that did not include a case study of a system exposed to a disaster triggered by a natural hazard and articles that did not use qualitative or quantitative analyzes to explore inequalities in the system's response to the disaster. This process yielded 43 articles. Secondly, the authors read the full text of each article for relevancy, using the same criteria from the first step. This reduced the final number of articles to 22.

We coded each article using predefined criteria (Appendix 1, coding criteria). To strengthen inter-coder reliability, two papers were initially coded by all coders and the results compared and discussed before coding the remaining papers. We first retrieved data on the context of each case study, including disaster, location, type of social-ecological system (e.g., city, country, island), the unit of analysis (e.g., household or neighborhood scale), and whether the article described the social-ecological system using Panarchy. We then retrieved data on the inequalities, and adaptive-cycle system characteristics, pre- and post-disaster (Fig. 1). Potential, connectedness, and resilience define what phase of the adaptive cycle the social-ecological system is in (Gunderson and Holling 2001). Identifying these three dimensions within each case study pre- and post-disaster can indicate whether the system transitioned post-disaster or remained "trapped". We categorized inequalities based on the inequality dimensions described in the World Social Science Report (ISSC et al. 2016): Economic; Political; Cultural; Environmental; Spatial; and Knowledge-based (Fig. 1). Because potential, connectedness, and resilience can also take a variety of forms within social-ecological systems, we also categorized these variables using the inequality-dimension categories, but we merged the social and cultural dimensions into a "social-cultural" dimension due to difficulty separating these dimensions, and we removed the spatial dimension as there is no information in the literature that defines spatial dimensions of the system characteristics (Fig. 1). For inequality, we also recorded the scale at which data were collected (e.g., individual, community) and who the disadvantaged groups were in relation to the inequalities discussed. Finally, we described how inequality interacted with potential, connectedness, and/or resilience and affected how the system reorganized, or not, after the disaster. This description was based on the authors' own interpretation of the system based on information collected on inequalities and system characteristics.

In our analyses, the different inequality dimensions identified were discussed independently of each other rather than assessing intersecting inequalities. This was due to many of the case studies considering inequalities in isolation, and we were unable to collect data on intersecting inequalities pre- and post-disaster. Though our approach simplifies inequalities, it provides information on where and how inequalities may influence the adaptive cycle, providing a starting point for integrating inequalities into adaptive-cycle models. (Appendix 1, full list of data collected)



**Fig. 1.** Inequality, potential, connectedness, and resilience dimensions within each case study. Adapted from World Social Science Report (ISCC et al. 2016).

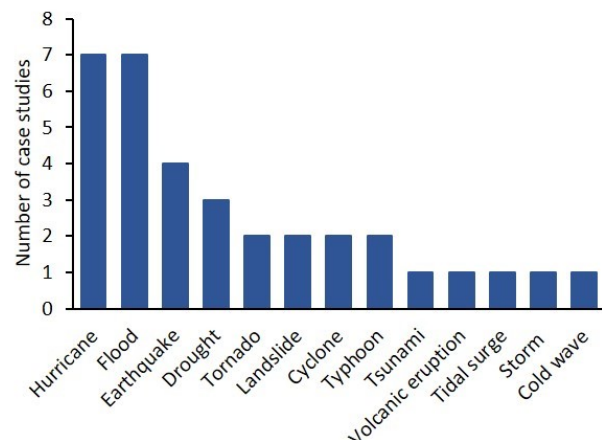
Variable	Dimensions
<b>Inequality</b> <i>Unequal distribution of resources among a population (Cowell 2011; ISCC et al. 2016)</i>	<b>Economic:</b> Differences in financial stability, income level, wealth and capital between groups of people <b>Political:</b> Differences in how power is distributed among governments, institutions, communities and individuals. <b>Cultural:</b> Differences in the level of discrimination experienced by different groups based on, for example, gender, ethnicity, race or religion. <b>Social:</b> Differences in the social status of different groups and access to, or functioning of, social services (such as education and health services). <b>Environmental:</b> Differences in how reliant groups of people are on ecosystems for quality of life, or their accessibility to it. <b>Knowledge:</b> Differences in how much knowledge is available or accessible to different groups of people. It also includes the notion of whose knowledge counts and what types of knowledge are taken into account. <b>Spatial:</b> Spatial and regional differences between groups in urban and rural areas.
<b>Potential</b> <i>The level of resources or productivity present within the system (Gunderson &amp; Holling 2001)</i>	<b>Economic:</b> Financial resources available <b>Political:</b> Resources and/or level of preparedness available within government departments to respond to a natural disaster (e.g., disaster management plans, emergency response staff well-equipped) <b>Social-cultural:</b> Cultural or social resources available (culture or social institutions that support response to disasters) <b>Environmental:</b> Natural resources available and/or their productivity <b>Knowledge:</b> Knowledge available on natural disaster management and recovery (e.g., memory of previous disasters, education)
<b>Connectedness</b> <i>The strength of internal connections that mediate the influences between inside processes and the outside world. A system with high connectedness is little influenced by external variability (Gunderson &amp; Holling 2001)</i>	<b>Economic:</b> Reliance of economy on internal or external sources of finance <b>Political:</b> Reliance of government and decision-makers on internal or external sources of disaster management and preparedness <b>Social-cultural:</b> Reliance on internal or external sources of culture, religion, and social institutions (including education, health, and social protection). <b>Environmental:</b> Reliance of the ecosystem on human intervention to function <b>Knowledge:</b> The amount of knowledge on disaster management that is shared within the system, and whether that knowledge is produced within the system or externally.
<b>Resilience</b> <i>The capacity of a system to absorb shocks and reorganize and recover (Walker et al., 2004; Sundstrom &amp; Allen, 2019; Cretney 2014)</i>	<b>Economic:</b> The capacity of the economy to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks. <b>Political:</b> The capacity of the political system (e.g., government) to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks <b>Social-cultural:</b> The capacity of the social-cultural system that supports different cultures, religions, and social institutions to absorb disturbance while undergoing change so as to retain essentially the same function, structure, identity, and feedbacks <b>Environmental:</b> The capacity of the ecosystem to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks <b>Knowledge:</b> Not identified – unable to be described in a context suitable for coding.

## RESULTS

The 22 papers included a range of case studies focusing on social-ecological systems before and after either a single disaster or a combination of disasters. The case studies discussed a range of disasters triggered by natural hazards, including hurricanes, drought, tornadoes, landslides, cyclones, and typhoons (Fig. 2). Seven case studies focused on Hurricane Katrina (USA), while the other case studies were located across North America, Central America, Asia, Africa, and Europe. One case study used Panarchy to discuss the changes in social-ecological systems related to inequalities (Chuang et al. 2019).

The case studies consisted of a diverse range of inequalities. Economic inequality was the most commonly assessed inequality dimension within the case studies (N = 19, Table 2). Economic inequality was measured using a variety of indicators, such as household assets and expenditures. Social and cultural inequality were both assessed in eight case studies. Types of social inequality assessed included access to healthcare, education, and social power, while cultural inequality included institutional and community discrimination based on gender, race, and social status. One paper each discussed political inequality, focusing on immigration statuses; knowledge inequality, focusing on coping strategies; and environmental inequality. Two papers discussed spatial inequality, both focusing on the unequal distribution of

**Fig. 2.** The frequency of natural hazard induced disasters discussed within the case studies. Five of the case studies assessed the system in response to multiple disasters, while seventeen case studies focused on a single disaster.



resources across different New Orleans neighborhoods pre- and post- Hurricane Katrina. The groups disadvantaged by the identified inequalities included, among others, women, African-Americans, Indigenous Peoples, migrants, and low-income households. (Appendix 2, full list of coded data)

**Table 2.** The number of case studies that assessed or discussed each dimension of inequality, and the potential, connectedness and resilience present within the system. "NA" refers to dimensions that were not relevant to inequality, potential, connectedness or resilience, and no information was therefore collected. Note that some case studies assessed or discussed multiple dimensions for each variable and therefore column totals may exceed the number of case studies examined (N=22).

Dimension	Inequality	Potential	Connectedness	Resilience
Economic	19	17	7	6
Political	1	1	1	0
Cultural	8	NA	NA	NA
Social	8	NA	NA	NA
Social-cultural	NA	3	7	3
Environmental	1	6	0	3
Knowledge	1	1	1	0
Spatial	2	NA	NA	NA
Not identified	0	3	10	13

Case studies varied in how potential, connectedness, and resilience were discussed (Table 2). The potential within the system, before and after the disaster occurred, was discussed in 19 case studies. The most assessed potential dimensions were economic (N = 17) and environmental (N = 6). Connectedness within the system was identified in 12 case studies, with economic and social-cultural connectedness most common (N = 7). Resilience was the least explicitly studied system characteristic, with 9 papers mentioning or inferring resilience. Importantly, changes in these system characteristics after the disasters were often attributed to different groups rather than to the system as a whole (Fig. 3).

We found that many case studies observed or inferred increases in inequality within the social-ecological systems after the disaster compared to pre-disaster levels (Fig. 3). In particular, increased inequality and decreased potential after a disaster was often observed. Often, the advantaged groups within the system experienced an increase in potential while the disadvantaged groups experienced a decrease (e.g., Prohaska et al. 2020, Downey and Reese 2017). High connectedness after the disaster was often associated with advantaged groups who did not need to rely on external sources of aid after the disaster as much as the disadvantaged groups, even though they were often better able to acquire this external support. Low connectedness was often associated with the disadvantaged groups, who were more reliant on external sources of support and aid after the disaster, most often through social-political pressure (e.g., Sheller 2013). Furthermore, as inequality increased, some case studies found that advantaged groups also became more resilient, while the disadvantaged groups became less resilient after the disaster (e.g., Bui et al. 2014).

Decreases in inequality after a disaster were less common among the case studies (N = 3, Fig. 3). A decrease in overall inequality and an increase in potential after a disaster was observed in one case study: New Orleans, after Hurricane Katrina (Downey and Reese

2017). However, this was because inequality was displaced. Many disadvantaged groups (e.g., low-income and African American households) either chose not to return to New Orleans to rebuild after the disaster or were forced to emigrate due to discriminatory rebuilding policies, while more middle- and upper-class households remained. Though this displacement contributes to a quantitative reduction in inequality within the system, as the inequality spectrum decreased, it contributes to amplifying inequalities at a larger scale. A decrease in both inequality and potential after a disaster was observed in two case studies: a long-term drought in Ethiopia where high-income households had more assets to lose than low-income households (Thiede 2014) and Cyclone Nargis in Myanmar which, due to the spatial location of impact, lead to some advantaged groups losing a greater amount of assets than the disadvantaged groups (Warr and Aung 2019).

Only one case study explicitly observed no change in the level of inequality observed before and after a disaster occurred (Linnekamp et al. 2011). This case study also observed an increase in resilience after flooding among disadvantaged groups, through increased property maintenance and disaster preparation (Fig. 3).

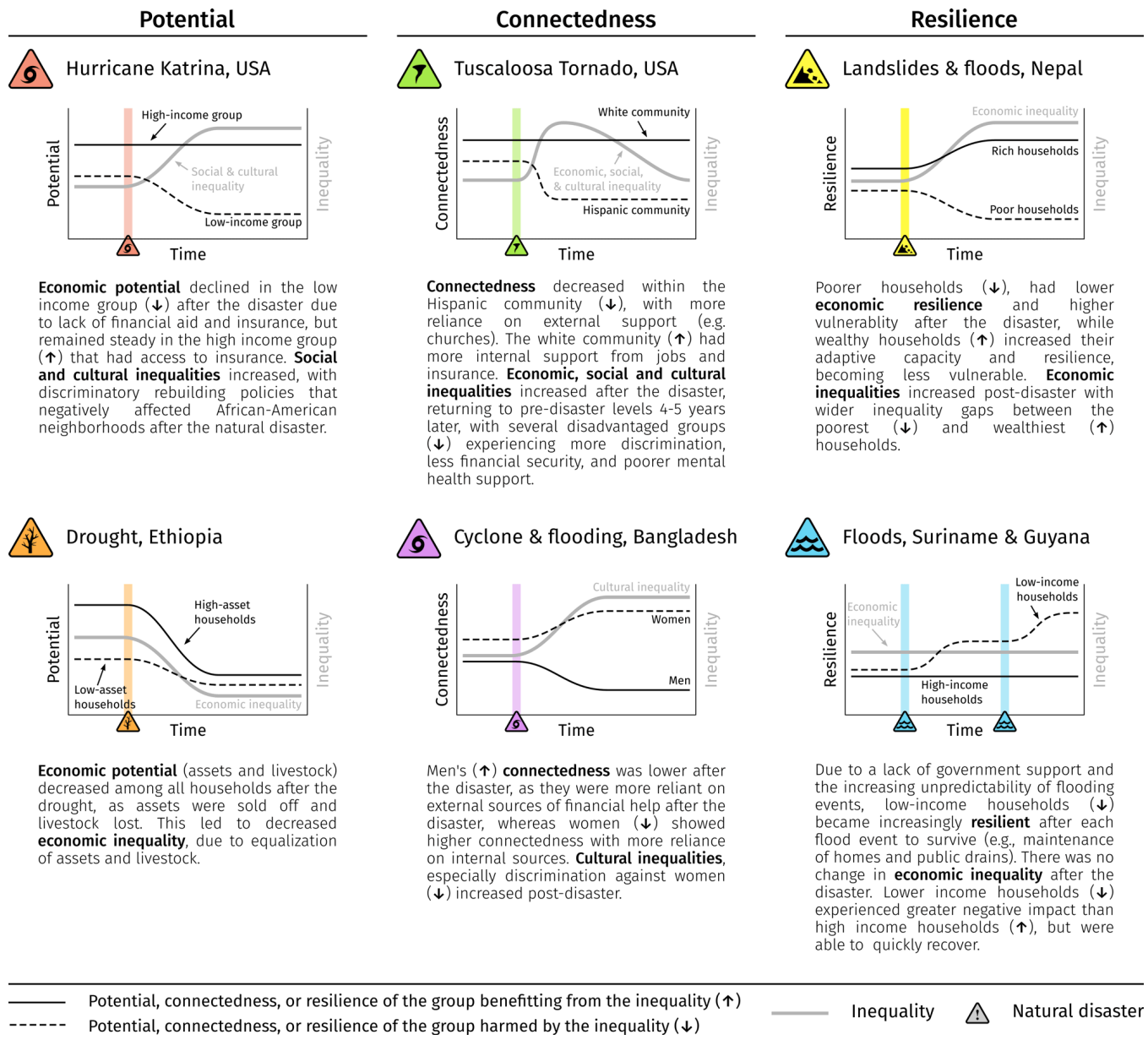
## DISCUSSION

Through observing adaptive-cycle system variables where inequalities are present, pre- and post-disaster, we sought to understand how inequalities affect the reorganization phase of the social-ecological systems' adaptive cycles. In Panarchy, reorganization occurs when a disturbance shifts a system from high potential (e.g., resources) to low, while maintaining connectedness, such as maintaining the amount that external sources of financial support or knowledge influence the system (Gunderson and Holling 2001). Our selection of case studies demonstrates that inequalities affect the reorganization phase of the adaptive cycle after a disaster. In particular, the case studies suggest that the more disadvantaged groups experience decreases in connectedness, being more influenced by external actors or drivers after a disaster (such as increased reliance on international aid), encountering a greater decrease in potential post-disaster than the more advantaged groups. Therefore, the ability and time frame for the more disadvantaged groups within the system to reorganize differs from that of the more advantaged groups, affecting the ability of the system as a whole to reorganize. Based on our findings, we developed three propositions that describe how inequality might influence the reorganization phase of a system's adaptive cycle in response to a disaster. These propositions can provide a first step to incorporating inequality mechanisms into social-ecological models based on Panarchy, improving resource allocation to enhance the likelihood of systems transitioning to more positive trajectories post-disaster.

### Proposition 1: Inequalities separate the system into distinct subsystems with different reorganization abilities.

Our selection of case studies illustrates that disasters occurring in unequal systems can exacerbate pre-existing inequalities. Thus, in terms of Panarchy, inequality maintains multiple subsystems within a broader social-ecological system, and each subsystem has its own adaptive cycle. This divide leads to the emergence of different trajectories after a disaster, with differences in speed of recovery, and how resilience, potential, and connectedness are distributed within these adaptive cycles. Most often, the more advantaged groups at the high end of the inequality spectrum (e.g., a high-income group, in the case of income inequality) stay the same or

**Fig. 3.** Trends in the potential, connectedness, and resilience present within the groups advantaged (↑) and disadvantaged (↓) by the inequality present following the disasters, from six case studies. The inequality line denotes the change in the size of the inequality gap between the more advantaged and disadvantaged groups before and after the disaster, with increasing inequality indicating a larger inequality gap between the groups. Figures are intended to illustrate general directional trends and may not be drawn to scale. Refer to Appendix 2 for further details on each case study.



become more resilient post-disaster, therefore, entering the reorganization phase of their adaptive cycle. Meanwhile, the more disadvantaged groups (e.g., a low-income group) become more at risk of entering a poverty trap (Carpenter and Brock 2008), unable to enter the reorganization phase, and the inequality gap widens. This situation was observed in a number of case studies (e.g., Walch et al. 2018, Elliott et al. 2009, Bista 2020). Our results also suggest that, even if no group becomes trapped, there can be a time lag in entering the reorganization phase due to inequalities

with more disadvantaged groups taking longer. This time lag could be due to the levels of potential, connectedness, and resilience present. For example, Prohaska (2020) found that low-income groups took longer to recover economically post-disaster due to lack of insurance coverage (potential).

Thiede et al. (2014) did document a decrease in the inequality gap after a drought. In this case study, poorer households stayed the same while richer households became poorer and did not reorganize to a more positive trajectory. This reduced-inequality



gap may occur when the assets (potential) of the high-income group are more sensitive to the disaster. However, this effect may be dampened by the ability of high-income households to access external support or diversify their assets (e.g., Fratkin et al. 1990).

Though our study did not consider intersecting inequalities, it is possible that they also form subsystems with different trajectories (e.g., a group marginalized by both ethnicity and gender experience may be in a different subsystem to those marginalized only by gender or ethnicity), but further investigation is required.

**Proposition 2: Interactions between subsystems may exacerbate inequalities.**

While different populations within societies may separate into different adaptive cycles after a disaster, our results suggest these adaptive cycles interact across the same spatial and temporal scales. Holling (2001) describes the assumption of nestedness in Panarchy, where different adaptive cycles are connected through feedback loops that maintain similarity within an adaptive cycle but differences between nested adaptive cycles.

We propose that our selection of case studies describe such feedbacks between adaptive cycles influenced by the inequalities present. We identified two types of reinforcing feedbacks among these adaptive cycles. Firstly, inequalities are often maintained within a system after a disaster when the more advantaged groups (or subsystems) are able to enter the reorganization phase at the expense of the disadvantaged groups (subsystems). This is also known as accumulation by dispossession (Hall 2013) and refers to the tendency of those benefiting from inequality to exploit disasters to increase their capabilities, such as enforcing discriminatory rebuilding policies (e.g., Green et al. 2007). Secondly, post-disaster relief is often not distributed equally potentially further preventing disadvantaged subsystems from entering the reorganization phase. This was observed by de Juan et al. (2020) where lack of land ownership prevented some individuals from receiving aid after Typhoon Haiyan in the Philippines. In some cases, both types of reinforcing feedbacks can be present, where inhibited potential, connectedness, and resilience are systematically exacerbated for the disadvantaged groups so that the other groups have greater potential to reorganize (e.g., Prohaska 2020). Furthermore, intersecting inequalities may exacerbate the speed and amplitude at which inequalities are exacerbated, complicating the interactions between subsystems (Crenshaw 1989).

**Proposition 3: Inequality influences the connectedness present after disasters.**

While previous research has highlighted the impact of disasters on resources, our results emphasize that connectedness between individuals and groups can strongly affect the ability of people to prepare for and cope with unexpected events and reorganize. These findings support the capability approach, which emphasizes that assessments of well-being should focus on the opportunities, including connections, available to people (Robeyns 2006). In the context of understanding the relationship between inequality and reorganization after a disaster, connectedness can occur at several scales that may influence the system in qualitatively different ways. Connectedness can occur within a subgroup (with respect to the inequality of interest), for example, the strength of social ties within a disadvantaged

neighborhood (Linnekamp et al. 2011); or between subgroups, for example, the relationships between residents of a disadvantaged neighborhood and local politicians (Downey and Reese 2017). A third scale is connections to areas that are outside the system and the scope of the disaster. These “global” connections can aid in people’s recovery in the short term, but may not lead to reorganization, and may even worsen the situation if they do not consider the underlying roots of inequality with the system at risk of becoming trapped. For example, international aid to communities in the Philippines in response to Typhoon Haiyan provided critical resources for recovery but, in the longer-term, disadvantaged groups felt dependent on these external resources and became trapped in their adaptive cycle, unable to reorganize into a more self-reliant system (Walch 2018). Resources coming from outside communities can also weaken connections at the local level, as has been observed when the resources are perceived as not being distributed equitably, which exacerbates the inequality gap and leads to the adaptive cycles of subsystems negatively interacting as discussed in proposition 2 (De Juan et al. 2020).

**Implications for social-ecological modeling**

Panarchy is a useful framework for developing social-ecological system models as it helps to predict when a system deviates from expected patterns of change in response to disturbances (Donner and Rodríguez 2008). However, currently there is a lack of information on the role of inequality dynamics within Panarchy, making it difficult to develop models that incorporate inequality dynamics (Lade and Niiranen 2017, Mathias et al. 2020). Our three propositions provide a way forward, indicating how inequality dynamics can be incorporated into Panarchy and shape our understanding of social-ecological systems and their structure in response to disasters. These propositions can provide the foundations for developing testable hypotheses for how social-ecological systems will respond to disasters and account for how inequality dynamics shape or are shaped by outcomes of disasters, which can be used to develop more complex quantitative models to further assess how a system is likely to reorganize after a disaster (Rufat et al. 2019). These quantitative models can improve disaster management, planning, and policy by identifying how a system is likely to respond to a disaster under different scenarios, which can in turn identify how resources and support should be distributed pre-and post-disaster to ensure all members of the system enter the reorganization phase.

**Future research**

It is well known that inequalities can affect a social-ecological system’s response to disaster, but inequality dynamics are rarely considered within Panarchy. Our study outlines approaches for better incorporating inequality into Panarchy to aid disaster planning, but further research is required. In particular, information on the common pathways through which inequality influences the adaptive cycle, and whether there is a relationship to the characteristics of the disaster itself, will be vital for disaster planning. This will require an extensive literature review that uses a greater range of search terms to capture all papers. For example, as well as identifying papers that consider inequality, papers including other terms that refer to the distribution of resources, such as equity and social justice, should be considered (Leach et al. 2018).

Further work is also required to better integrate intersecting inequalities into Panarchy. Here, we assessed inequalities dimensions independently. However, inequalities are complex and can interact, and there is an increasing call to recognize that a person can be both advantaged and disadvantaged, based on the different inequalities present (Leap 2018). While our study provides an initial understanding of inequalities within the adaptive cycle, further research is required to collect empirical data on intersectional inequalities within social-ecological systems that can enable better integration of intersectional dimensions of inequalities into Panarchy models (Kadetz and Mock 2018). Also, due to the heterogeneous and complex nature of social-ecological systems, it is difficult to meaningfully identify and measure system variables and inequality on a system-wide scale (Levin et al. 2013, Walker et al. 2006). We recommend that future research focuses on how we can both conceptually and empirically assess inequality and the system variables at the system-wide scale to improve both our understanding of the adaptive cycle and improve social-ecological modeling.

## CONCLUSION

Understanding the role of inequalities in the reorganization of social-ecological systems after disasters triggered by natural hazards is vital for designing disaster recovery policies that improve the likelihood of a system transitioning to a more positive and resilient trajectory after the disaster. By applying the Panarchy framework, we identified three propositions that describe the role of inequalities in the reorganization of a system. Our findings suggest that inequalities affect the ability of different individuals to reorganize after a disaster, creating subsystems with different adaptive cycles that move onto different trajectories following a disaster, and that system connectedness can strongly interact with inequality. Our findings can inform future models of social-ecological systems to help proactively improve the likelihood that systems will move to better trajectories following disasters, and help to better allocate resources and design post-disaster recovery, particularly in areas subject to more frequent and intense disasters.

*Responses to this article can be read online at:*  
<https://www.ecologyandsociety.org/issues/responses.php/13456>

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## Data Availability:

*Data/code sharing is not applicable to this article. All data coded in the literature review is provided in the appendices.*

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## Appendix 1. Literature review coding information

**Table A1.1.** Details of the data extracted from each article in the literature review.

Variable	Categories/description
Paper title	-
Authors	-
Year of publication	-
Country	Country(ies) where the case study is located.
Disaster	Type of natural hazard triggered disaster discussed in the case study (e.g., hurricane, tsunami).
Inequality dimensions identified (based on World Social Science Report 2016) <sup>1</sup>	<p>Economic (E): Differences in financial stability, income level, wealth and capital between groups of people.</p> <p>Political (P): Differences in how power is distributed among governments, institutions, communities and individuals.</p> <p>Social (So): Differences in the social status of different groups and access to, or functioning of, social services (such as education and health services).</p> <p>Cultural (C): Differences in the level of discrimination experienced by different groups based on, for example, gender, ethnicity, race or religion.</p> <p>Environmental (ENV): Differences in how reliant different groups of people are on ecosystems for quality of life, or how much access they have to it.</p> <p>Knowledge (K): Differences in how much knowledge is available or accessible to different groups of people. It also includes the notion of whose knowledge counts and what types of knowledge are taken into account.</p> <p>Spatial (Sp): Spatial and regional differences between groups in urban and rural areas.</p>
Relevant inequality quotes	Quotes from the article that support the inequality dimensions identified.
Change in inequality identified post-disaster	Describe how inequality changed post disaster (e.g., did the inequality increase or decrease).
Scale at which inequality was assessed	For example, individual, household, community, city.
Disadvantaged groups identified	List the disadvantaged groups, in relation to the inequality identified (e.g., low-income individuals, specific ethnic groups).
Inequality outcome	The final outcome or impact, if changes in inequality occurred post disaster (e.g., reduced social conflicts).
Type of system	Describe the type of socio-ecological system assessed (e.g. island, city, country).
Unit of analysis	Describe the unit or scale at which characteristics of the system are measured or described (e.g., Is the paper talking about the potential or connectedness of particular people, or the system as a whole?).
Discusses Panarchy	Describe if the paper discusses the case study in the context of Panarchy. If not, then it is assumed we are extrapolating for system characteristics.
Discusses resilience	Describe if the paper discusses the case study in the context of resilience.
Notes on Panarchy/resilience	Notes from coder on other relevant points related to how Panarchy or resilience are discussed or framed within the article.



Potential dimensions identified (the level of resources or productivity present within the system) <sup>2</sup>	Economic (E): Financial resources available. Political (P): Resources and/or level of preparedness available within government departments to respond to a natural disaster (e.g., disaster management plans, emergency response staff well-equipped). Social-cultural (SC): Cultural or social resources available (culture or social institutions that support response to disasters). Environmental (ENV): Natural resources available and/or their productivity. Knowledge (K): Knowledge available on natural disaster management and recovery (e.g., memory of previous disasters, education).
Relevant potential quotes	Quotes from the article that support the potential dimensions identified.
Potential, post disaster	Describe how potential available changed post-disaster (e.g., did it increase or decrease).
Connectedness dimensions identified (the strength of internal connections that mediate and regulate the influences between inside processes and the outside world. A system with high connectedness is little influenced by external variability) <sup>2</sup>	Economic (E): Reliance of economy on internal or external sources of finance. Political (P): Reliance of government and decision-making processes on internal or external sources for disaster management and preparedness. Social-cultural (SC): Reliance on internal or external sources of culture, religion, and social institutions (including education, health, and social protection). Environmental (ENV): Reliance of the ecosystem on human intervention to function. Knowledge (K): The amount of knowledge on disaster management that is shared within the system, and whether that knowledge is produced within the system or externally.
Relevant Connectedness quotes	Quotes from the article that support the connectedness dimensions identified.
Connectedness, post-disaster	Describe how connectedness changed post-disaster (e.g., did it increase or decrease).
Resilience dimensions identified (the capacity of a system to absorb disturbance and reorganize while undergoing change, so as to retain the same function, structure, and identity)	Economic (E): The capacity of the economy to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks. Political (P): The capacity of the political system (e.g., government) to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks. Social-cultural (SC): The capacity of the socio-cultural system that supports different cultures, religions, and social institutions to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks. Environmental (ENV): The capacity of the ecosystem to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks. Knowledge (K): Not identified – unable to be described in a context suitable for coding.
Relevant Resilience quotes	Quotes from the article that support the resilience dimensions identified.
Resilience, post-disaster	Describe how resilience changed post-disaster (e.g., did it increase or decrease).
Outcome for system level Panarchy	Describe briefly, in the context of Panarchy, how inequality interacted with potential, connectedness and/or resilience and affected how the system reorganised or not (e.g. traps) after the natural disaster.
Takeaway messages from the paper	Notes from coder on the main take home messages from the article.

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<sup>1</sup>ISSC et al. (2016)

<sup>2</sup>Gunderson and Holling (2001)

<sup>3</sup>Walker et al. (2004)

<sup>4</sup>Sundstrom and Allen (2019)

## Appendix 2. Literature review results

**Table A2.1.** Details of the final 22 articles identified in the literature review.

Paper ID	Reference	Date coded
1	Fratkin, E., and E.A. Roth. 1990. Drought and economic differentiation among Ariaal pastoralists of Kenya. <i>Human Ecology</i> 18(4): 385-402.	21/11/2020
2	Bankoff, G. 1999. A history of poverty: The politics of natural disasters in the Philippines, 1985-95. <i>The Pacific Review</i> 12(3): 381-420.	16/11/2020
7	Fielding, J. 2007. Environmental Injustice or Just the Lie of the Land: An Investigation of the Socio-Economic Class of those at Risk from Flooding in England and Wales. <i>Sociological Research Online</i> 12(4): 12-34.	20/11/2020
8	Green, R., L.K. Bates, and A. Smyth. 2007. Impediments to recovery in New Orleans: Upper and Lower Ninth Ward: one year after Hurricane Katrina. <i>Disasters</i> 31(4): 311-335.	20/11/2020
15	Johnson, G.S. 2008. Environmental Justice and Katrina: A Senseless Environmental Disaster. <i>Western Journal of Black Studies</i> 32(1).	11/02/2020
16	Ruwanpura, K.N. 2008. Temporality of disasters: The politics of women's livelihoods 'after' the 2004 tsunami in Sri Lanka. <i>Singapore Journal of Tropical Geography</i> 29(3): 325-340.	30/10/2020
18	Elliott, J.R., A. Bellone Hite, and J.A. Devine. 2009. Unequal Return: The Uneven Resettlements of New Orleans - Uptown Neighborhoods. <i>Organization &amp; Environment</i> 22(4): 410-421.	26/10/2020
20	Shaughnessy, T.M., M.L. White, and M.D. Brendler. 2010. The Income Distribution Effect of Natural Disasters: An Analysis of Hurricane Katrina. <i>Journal of Regional Analysis and Policy</i> .	21/10/2020
22	Linnekamp, F., A. Koedam, and I.S.A. Baud. 2011. Household vulnerability to climate change: Examining perceptions of households of flood risks in Georgetown and Paramaribo. <i>Habitat International</i> 35(3): 447-456.	21/10/2020
24	Ajibade, I., G. McBean, and R. Bezner-Kerr. 2013. Urban flooding in Lagos, Nigeria: Patterns of vulnerability and resilience among women. <i>Global Environmental Change</i> 23(6): 1714-1725.	21/10/2020
27	Sheller, M. 2013. The islanding effect: post-disaster mobility systems and humanitarian logistics in Haiti. <i>Cultural geographies</i> 20(2): 185-204.	21/10/2020
28	Bui, A.T., M. Dungey, C.V. Nguyen, and T.P. Pham. 2014. The impact of natural disasters on household income, expenditure, poverty and inequality: evidence from Vietnam. <i>Applied Economics</i> 46(15):1751-1766.	21/10/2020



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**Table A2.2.** Inequality, potential, connectedness and resilience dimensions identified in each case study. E = Economic; So = Social; C = Cultural; SC = Social-Cultural; P = Political; Env = Environmental; K = Knowledge; Sp = Spatial. Dimensions not mentioned in a case study are represented by a dash. Social, cultural and spatial dimensions were only assessed for inequality, and the social-cultural dimension was only assessed for potential, connectedness and resilience. See Table A2.1 for the paper associated with each Paper ID number.

<b>Paper ID</b>	<b>Inequality</b>	<b>Potential</b>	<b>Connectedness</b>	<b>Resilience</b>
1	E	E	E	-
2	E; So	E; P; Env	E	E; Env
7	E; So	K	-	-
8	E; Sp	E	-	E
15	So; C	E; SC	-	-
16	So; C; E	E	E	E; Env
18	C	E	SC	-
20	E	E	-	-
22	E	-	K	SC
24	C; E	-	-	E
27	So; E	Env; E	E; P	-
28	E	E	-	Env
30	E	E; Env	-	-
31	C; K; E	-	E; SC	-
33	C; E	E; Env	SC	-
34	So; C	E	SC	-
36	E; So	P	SC; E	SC; E
38	E; Env; C; Sp	E; Env	-	-
40	E	E	-	-
41	E	E; SC; Env	-	E
42	E; So	E; SC	SC	-
43	P; E; So; C	E	SC; E	SC

**Table A2.3.** Changes in inequality, potential, connectedness and resilience observed within each case-study’s socio-ecological system. A dash indicates that no information was provided for the case study.

Paper ID	Case study	Type of system	Changes in inequality, potential, connectedness, and resilience observed after natural disasters			
			Inequality	Potential	Connectedness	Resilience
43	Tuscaloosa Tornado, USA	City	Inequality increased directly after the disaster, but slowly returned to pre-disaster levels 4-5 years after disaster. Low-income households, Latina, people without citizenship and women were less likely to have insurance, more likely to lose their jobs, and less likely to get mental health help.	Economic potential decreased post disaster for disadvantaged people as the tornado resulted in the worsening of already precarious financial situations.	After the disaster, the Hispanic community relied more on external sources of money and culture (e.g., the Church).	Health, education and social support for immigrants and Latina people was low before and after the disaster, making these groups less resilient.
42	Earthquake, Nepal	Country	Due to structure of disaster response, poorer families had less access to government aid which exacerbated pre-existing inequalities.	Poorer households did not access aid, thus reducing their economic potential.	Connectedness varied and depended on who could access external financial aid.	-
41	Landslide & Flood, Nepal	Watershed	Economic inequality and social-cultural inequality was exacerbated by the disaster.	Economic loss occurred after the natural disaster. About 69% households were mostly affected.	-	The disaster led to lower resilience in the low-income population.
40	Cyclone Nargis, Myanmar	Country	Economic inequality decreased at the national scale post-disaster but increased at the local scale.	The natural disaster increased the number of people with expenditures below the poverty line.	-	-
38	Hurricane Katrina, USA	City	Income inequality increased spatially over time after the natural disaster.	Temporally, the income potential increased. However, spatially, different levels of income groups were more clustered after the hurricane.	-	-
36	Typhoon Haiyan, Philippines	Island	Likely increase in inequality because root causes of vulnerabilities were not	-	Huge social mobilisation at the local level after the	Informal settlers and migrants had lower resilience due to lack of



			addressed. Further marginalisation post-disaster because even less land was available than before, increasing demand and conflict for land.		disaster, and temporary but strong economic reliance on government and external support.	access to land and land tenure, which worsened after the disaster.
34	Hurricane Katrina, USA	City	Social and cultural inequalities increased significantly directly after the disaster, and then returned mostly to prior levels.	Economic potential increased as many low-income households emigrated from New Orleans due to lack of support for rebuilding within their communities. This left the city with a higher proportion of middle-class residents.	Due to poor infrastructure planning, many neighbourhoods did not have access to basic needs and were forced to leave or rely on external sources of support long after the disaster.	-
33	Earthquake, Haiti	Country	Cultural inequality increased. Women had a higher probability of being victims of intimate partner violence one to two years after the earthquake.	Decrease of economic potential, especially for women, primarily due to loss of employment.	Natural disaster reduced some women's access to social networks.	-
31	Flood, cyclone & tidal surge, Bangladesh	Country	Paper hypothesises that cultural inequalities increased post-disaster. Gender-based differences in access to knowledge, in cultural norms, and in household work and responsibilities, often mean women are hit harder by natural disasters.	-	Increased reliance on external financial help. Suggests low connectedness after disaster. Furthermore, men were more reliant on external sources of coping, with woman relying more on internal connections.	-
30	Drought, Ethiopia	Agricultural community	Inequality was reduced in response to the natural disaster. Assets and livestock numbers among households equalised under the drought.	Assets and livestock generally decreased after the natural disaster, as assets were sold off and livestock were lost.	-	-
28	Storm, flood, landslide, tornado & cold wave, Vietnam	Country	Inequality increased after the disaster, in the form of expenditure differences.	Decreased economic potential after the natural disaster, manifested by	-	Economic inequality affected resilience levels in the system. Poor households were

			21.6% of the exposed households live below the poverty line. If these households were not exposed to natural disasters, the poverty index would have been of 18.9%.	decreased household income and expenditure.		more exposed to natural disasters, decreasing their resilience.
27	Earthquake, Haiti & Hurricane Katrina, USA	Country (Haiti), City (USA)	Social inequalities were displaced. People without a social network had low ability to relocate, so they stayed and their situation often degraded, while those with access to a mobility network moved out of the country.	Environmental potential decreased after the disaster due to poor waste infrastructure.	Connectedness decreased as reliance on external support increased after the disaster. Influenced by Neocolonial and military power relations.	-
24	Flood, Nigeria	City	Gender inequality was more pronounced after the natural disaster.	-	-	Recovery was difficult for low-income women due to less social choice, and fewer financial resources. But their psychological resilience was strong.
22	Flood, Suriname & Guyana	City	Lower income areas had greater negative impact from the disaster but were also more prepared, due to building maintenance and preparation. There was no change in the inequality gap post-disaster.		Low-income household connectedness increased, as they relied on local knowledge and neighbours to recover and prepare for natural disasters. High-income households relied more on government agencies.	Due to lack of resources and increasing unpredictability of flooding events, low-income households became increasingly resilient to survive.
20	Hurricane Katrina, USA	City	Income inequality decreased. Gini Coefficient decreased after the natural disaster.	Economic potential increased due to emigration of mostly low-income and African American households, while middle and higher	-	-

				income households remained.		
18	Hurricane Katrina, USA	City	Cultural inequality was exacerbated because neighbourhood rebuilding was racially discriminatory, with predominantly white neighbourhoods resettled first.	African-American households had less financial resources after the natural disaster than White Americans.	The African-American community was more reliant on external social-cultural and economic resources, such as the Church, post-disaster.	-
16	Boxing Day Tsunami, Sri Lanka	Town	Economic and social and cultural inequalities, across both genders and ethnic groups, increased after the natural disaster.	Economic activity of some ethnic groups increased due to entrepreneurial efforts.	Women relied on external assistance to explore alternative livelihoods.	Entrepreneurial and shift to sustainable livelihoods increased resilience of women post-disaster.
15	Hurricane Katrina, USA	City	Inequalities were exacerbated post-disaster due to discriminatory rebuilding policies, plans, and insurance schemes.	Employment opportunity has generally decreased, decreasing economic potential.	-	-
8	Hurricane Katrina, USA	City	Economic inequality increased after the disaster as low-income neighbourhoods faced more barriers to rebuilding than high-income neighbourhoods.	High-income neighbourhoods were more likely to have insurance and be able to maintain their financial resources.	-	Resilience increased for high-income neighbourhoods, but decreased for low-income neighbourhoods, due to locations and the cost of insurance.
7	Flood, UK	Floodplain	Unclear if inequalities changed after the natural disaster.	Lack of knowledge on natural disasters within vulnerable groups, before and after the natural disaster.	-	-
2	Earthquake, typhoon, volcanic eruption, flood & drought, Philippines	Country	Economic inequality increased due to the increase of social-cultural inequality after disasters.	Decreased economic potential after natural disasters.	Reduced connectedness in response to natural disaster, due to reliance on shipping exports.	The poor and marginalised often reside in unsafe areas, have substandard housing, are malnourished, and lack financial safeguards,



						reducing their overall resilience before and after natural disasters.
1	Drought, Kenya	Pastoral community	Inequality increased post-disaster. High-income households tended to stay rich, and middle and low-income households became poorer.	Economic potential decreased among all households (but decreased less in the high-income households).	The low-income households were more reliant on external sources of income after the drought, such as jobs in the city and working for other households.	-



### **Appendix 3. Literature cited in the appendices**

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