Adjustment or transformation? Disaster risk intervention examples from Austria, Indonesia, Kiribati and South Africa

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ABSTRACT

Change triggered by natural hazards such as pluvial and coastal floods, sea-level rise as well as risks resulting from water scarcity are highly dynamic and related to the effects of ongoing climate change. Whether and how societies adapt, adjust, change, or transform because of climate change and related risks, is a currently debated topic. This question demands revisiting and comprehensively addressing existing theoretical foundations of transformations in risk management strategies and in risk governance to find effective ways to deal with climate change effects and their social consequences. Hence, the paper discusses current developments in transformation research and exemplifies this discussion with four interdisciplinary cases, which the co-authors reported in previous publications. Findings from Austria include a governance change within flood risk management related to zonation. Relocation in Indonesia and Kiribati showcases its cultural, behavioural as well as economic implications. Water scarcity in South Africa underlines the importance of behavioural change to enable the structural storage of rainwater. This paper analyses aspects of adjustment or transformation in these four examples. This may inform risk managers, decision-makers, practitioners, and planners dealing with natural hazards related to climate change how to conceptualise their (re-)actions.

1. Introduction

In the field of environmental change and societal risk, transformation is currently a highly-debated concept, including research on climate change risks (IPCC et al., 2021; Pelling et al., 2015), related extreme events (Gibson et al., 2016), sustainability (Elmqvist et al., 2019) and development (Thomalla et al., 2018). For example, it is debated whether transformation is part of or different from similar terms such as

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0264-8377/© 2022 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).
resilience (Pelling, 2010; Solecki et al., 2017). However, it is difficult to disentangle the related terms of adaptation, adjustment, change, and transformation. Hence, as a first step, we approach a better understanding of the partly subtle differences by simply providing definitions of the Oxford Dictionary (Table 1). In the course of the paper, we will slowly increase the complexity of the terms when needed.

As can be seen in Table 1, change is the simplest term of all and at the same time the foundation of all other terms: It simply means (1) the process because of which something becomes different to what it was before, and (2) it can also describe the result of something becoming different. Transformation, in contrast, can be regarded as the superlative of change, as it means something is completely changing. In literature (e.g., IPCC, 2019a), however, it is often used in a somewhat weaker and vague sense of fundamental changes instead of complete changes, where it remains unclear as to when a change is to be considered fundamental. But we can agree that transformation means moving on or rather transforming to a new system state (be it due to fundamental or complete changes within a given system). In contrast, the two remaining terms adaptation and adjustment describe a change with a specific purpose. In the case of adaptation, the purpose is to better suit a given situation. It’s about fitting the purpose. Adjustment, in contrast, is about improvement, to change something to make it better. For the following paragraphs and until potential refinement of the terms, the terms are used in these respective meanings. As adaptations as well as adjustments are part of transformation processes, the aim of this paper is to discuss how the terms can inform Disaster Risk Reduction without establishing a hierarchy of terms.

Whilst much of the early discussion on transformation (or what was labelled as such) centred on climate change mitigation and the need to fundamentally change the current political economy away from carbon lock-ins (Dangerman and Schellnhuber, 2013), much of the more recent debate has focused on the risks of environmental change, including how and to what extent transformation is necessary for the way societies deal with natural/environmental hazards (IPCC, 2019b). Environmental hazards can trigger transformation with an impact on land-use policies and public discussions about them (Jeffers, 2020; Thaler et al., 2017). Living with risks such as floods can trigger wider additional changes such as adjustments of building types, environmental management, land use and risk culture (UN/ISDR, 2004), with significant long-term effects. However, managing disasters often requires fast decisions and it remains unclear which type of intervention has which short-, mid-, or long-term impact (Noy, 2018). As a consequence, studies on lessons learned and long-term monitoring are demanded in the field of disaster risk reduction (United Nations, 2015), for instance in the Sendai Framework. The Sendai Framework for Disaster Risk Reduction is a leading guiding document of the United Nations highlighting strategic goals and risk measures for 2015–2030. In reaction, studies on monitoring disaster risk are emerging (Walz et al., 2020), with the aim to help direct future policies. However, while such studies emerge for monitoring, the current surge of conceptual writings on transformation still stands in opposition to a grave lack of empirical examples. This is the first gap this paper addresses by adding studies on lessons to still being learned from empirical work in different case studies.

Which actions and processes result in transformation is a second gap identified (Few et al., 2017), as well as the question when and why adjustment or adaptation might be the realistic or sufficient goal. This gap extends to influencing, enabling, and hindering factors of adaptation, adjustment, and transformation and how they might be stimulated in future (IPCC, 2019b; Solecki et al., 2017). Furthermore, there seems to be a limited understanding of which actions actually result in the transformation of responses to disaster risk, and different types of actions, both physical and social measures and processes, are thus analysed in this paper. Influencing factors need to be broken down into conceptual components that can then be systematically compared with each other, and their respective stimulations, or triggers and feedbacks. This paper attempts to fill this gap by re-analysing case studies with respect to adaptation, adjustment, change, and transformation.

Transformation is a new buzzword in research and it may be informative to fellow researchers whether their previous studies indeed did already capture aspects of transformations, or not. This can provide a rich body of existing empirical research that can then be re-analysed and therefore enormously expand the temporal span of studies. Aspects of change captured by existing studies are for example change detections of land use or changes in governance regimes. Characteristics of adjustments such as flood protection measures, insurance interventions or behavioural aspects of residents are investigated in research at least since Gilbert White’s seminal studies on flood risk development since the 1930s (White, 1945).

The examples presented in this paper have been selected from different continents to avoid contextual myopia, and are restricted to our own previous empirical research because of our in-depth and detailed knowledge of these studies. Our first aim is to offer a range of perspectives; it is not our aim to generalise from disjunct examples. Secondly, we want to facilitate a more conscious use of the terms adaptation, adjustment, and transformation in practical terms so as to guide case study assessments. The common denominator is water-related hazards, which will help to illustrate commonalities in identifying and analysing whether changes represent adaptation, adjustment, or transformation. We have selected case studies that display a variety of water-related issues; too much water as in the case of floods, tsunami, and sea-level rise, but also water shortage as in the case of droughts. One example is of river floods in Europe, i.e., Austria, where land-use policies have a long tradition. Austria has been a forerunner in implementing flood zonation legislation, long before the EU flood directive. A second example is from Asia, Indonesia, which is a region affected by multiple natural hazards. In Kiribati Oceania, sea-level rise will probably force the relocation of the whole population. Finally, in South Africa the Cape Town water crisis experience shows ways of dealing with water scarcity and droughts, avoiding a day zero of water shortage.

The following research question guides this paper: What is the difference between adaptation, adjustment, change, and transformation in water-related risks that can be concluded from disaster risk reduction (DRR)?

To answer this question, we qualitatively analysed a broad range of scientific publications covering conceptual, theoretical, and empirical research (including, as mentioned above, our own publications and findings). Iterations in analysing and discussing these three sorts of research contributions led to a simplified conceptual framework that then was used to structure the short case study illustrations for this paper. In sum, this paper is the result of desktop research on a conceptual level based on our own previous empirical work.

The structure of the paper is as follows: Section 2 encompasses a brief overview of concepts and definitions of adaptation, adjustment, change, and transformation. In Section 3, examples are presented to demonstrate the variety of conceptual aspects that need to be considered when addressing changes (specifically, adjustments and transformations) in disaster risk management and governance. Building on the examples,

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**Table 1**

<table>
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<tr>
<th>Adaptation</th>
<th>Adjustment</th>
<th>Change</th>
<th>Transformation</th>
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<tbody>
<tr>
<td>The action or process of changing something, or of being changed, to suit a new purpose or situation.</td>
<td>A small change made in order to improve it.</td>
<td>The act or result of something becoming different.</td>
<td>The process or a period of changing from one state or condition to another.</td>
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</table>
2. Concepts and definitions of adaptation, adjustment, and transformation

As the effects of climate change lead to an increased frequency and severity of extreme events such as droughts, heavy rain, riverine, and pluvial floods, one important question is how measures for climate change adaptation can be integrated into DRR (Schipper, 2009). Another question is how adjustment and transformation interventions are different or similar. To address the latter question, a transformation framework is developed that integrates perspectives from transformation and adaptation research.

2.1. Definitions of transformation and related terms

As can be seen in Table 2, some of the definitions for adaptation, adjustment, and related terms such as transformation are more complex, but also somewhat blurred. Some definitions even use one term to define the other, resulting in a lack of clarity, and, possibly, circular reasoning. After consulting the Oxford dictionary (cf. Table 1) it comes as a surprise how the sciences seem to struggle to distinguish adaptation, adjustment, and transformation. For instance, the difference between adaptation and transformation in the understanding of the IPCC (2012) is that transformation affects fundamental attributes, whilst adaptation for them means a better fit and an improvement of the risk situation – as you can see, the somewhat more selective definition of the Oxford Dictionary of adaptation (a better fit) and adjustment (an improvement) gets a little blurred here. And as already stated above, the question remains as to when a change can be considered as fundamental.

Schneidewind (2018) sees the need for transformative literacy, meaning the ability to ultimately shape change at all levels of society in such a way that modern society enables a good life without exploiting the earth and people. In the WBGU’s (2011) understanding (cf. Table 2), a transformation is a profound change in society that describes a transition into a new and different form of society, as has happened twice in the past: the Neolithic Revolution and the Industrial Revolution. Transformation therefore means something other than the only constant in the universe according to Heraclitus, change; transformation is deeper, more comprehensive and not constant, but limited in time, not unlike a revolution (Elverfeldt and Hagedorn, 2022). However, the term revolution could wrongly suggest that transformations take place suddenly and in a targeted manner. In contrast, the example of the Neolithic Revolution particularly shows that the transformation likely took place through many small, non-simultaneous ‘revolutions’ in different places and, above all, lasted over a long period of probably several millennia – the Neolithic Revolution was a slow process, not a sudden, abrupt, and all-encompassing change. Accordingly, the Industrial Revolution also took a relatively long period of around 100 years and was characterised by a lack of simultaneity, just like the Neolithic Revolution. In summary, for the transformation of our society from an exploitative one to a sustainable one, a look in the past teaches us that it (1) takes time, (2) it will take place at different speeds in different places, and (3) it seems unlikely that it will be initiated by those in power, since it potentially eliminates the structures on which their power rests (WBGU’s, 2011).

Bassett and Fogelman (2013) identified three different adaptation concepts in climate change literature: adjustable, reformist, and transformative approaches (Bassett and Fogelman, 2013). In this understanding, adjustment and transformation are different degrees of adaptation to change. All three ways imply different strategies for reducing vulnerability that has been discussed in hazard research and in disaster risk reduction since the late 1970s. The adjustment approach mostly implies top-down solutions (Hillmann et al., 2015; Schipper, 2007) and thereby might disregard socio-political root causes of

<table>
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<th>Table 2</th>
<th>Definitions of various terms in the context of adaptation, adjustment, change, and transformation as defined in the literature.</th>
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<tr>
<td><strong>Adaptation</strong></td>
<td>In glossaries dealing with climate change, adaptations are described to be “processes of adjustment (IPCC, 2018; UNFCCC, 2021). Incremental adaptation maintains the essence and integrity of a system or process at a given scale” (IPCC, 2018).</td>
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<tr>
<td><strong>Adjustment</strong></td>
<td>White (1945): White understands adjustment as a reaction to flooding such as land elevation, flood abatement in the sense of upstream land-management, engineering solutions for flood protection etc. White claims that a multitude of different measures is required for adjustment. Adjustments, as White (1945) used it, refer to changes that involve land use policies, and hence, long-term processes. They still maintain some essence or integrity of a given system, hence, can be incremental.</td>
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| **Transformation** | According to the IPCC SR1.5 (2019), transformation is “a change in the fundamental attributes of natural and human systems.” This is often the case for floods, water scarcity or related hazard events. “Societal (social) transformation” is defined as “a profound and often deliberate shift initiated by communities…” (ibid.). Transformation “includes value systems; regulatory, legislative, or bureaucratic regimes; financial institutions; and technological or biological systems” (IPCC, 2012, p. 564). Gibson et al. (2016) understand transformation as a step beyond “copying within and adapting to dominant development contexts” and understanding “build back better” as reconstruction only. According to the WBGU (2011, p. 5), the term great transformation means a “worldwide remodelling of economy and society towards sustainability” in which “production, consumption patterns and lifestyles in all of the three key transformation fields must be changed in such a way that global greenhouse gas emissions are reduced to an absolute minimum over the coming decades, and low carbon societies can develop”.
| **Institutional change** | “Institutions are the structure that humans impose on human interaction” (North, 2018). Important aspects to consider when analysing institutional change are change agents, sources, processes and directions, including pathways (ibid.). Agents of change can be individuals as well as organisations. People and their choices are constrained by those organisational forms. “Sources of change are the opportunities perceived” by agents of change (ibid.). In the context of climate change this involves both hazard-induced changes as well as human reactions and activities resulting from climate change. Processes of change are mainly incremental, and path-dependent, although revolutionary changes can also occur.
| **Transition** | Transitions include stages from niche innovations over new conceptual overlaps between the two concepts (Pelling, 2011). Another area of transformation research is urban governance, analysing measures and changes concerning sustainability (Mendizabal et al., 2018). The transition from one phase to another or more, related to a systems approach and typical project management phases, is proposed as a model for urban decision makers to integrate adaptation pathways with transition in other sectors such as infrastructure (Mendizabal et al., 2018). Transition often seems to be connected to notions of governance, where it is part of the policy pathways to achieve certain (strategic) goals (Pelling et al., 2015).
| **Adaptive Pathways** | Adaptive pathways are related to transformation. It is illustrative that ‘climate-resilient pathways’ are described as “opportunity spaces” between the present state and many possible future alternatives (IPCC, 2014). Hence, adaptive pathways, as well as resilience transitions, are often used to connect the concept of resilience to climate or economic development. The topic of adaptive pathways and transitions also appears in contexts of economical or digital transformation, for example (Rassow et al., 2019). It is increasingly used in many areas related to the SDGs such as education, gender, and health (Elmqvist et al., 2019). |
vulnerability and anthropogenic climate change. When remembering the original meaning of adjustment (cf. Table 1), it might become understandable as to why adjustment often is a top-down-approach: In general, it is effective to induce small changes from the top. Some approaches, however, advocate for a more radical system change, sustainable development (Watts and Bohle, 1993), and societal transformation as the most viable way to reduce vulnerability and strengthen adaptation capacity (Schipper, 2007). At the same time, transformative adaptation is “a complex concept that remains poorly defined in practice” (Fedele et al., 2019). Conceptual components include separations of phases and degrees of transformation. Similar to the meaning of the term “transformation” as explained by the Oxford dictionary, Kates et al. (2012) see transformation as some kind of superlative, but not as a superlative of “change”, but as a superlative of adaptation: Transformational adaptation is needed when incremental adaptation is insufficient. In their understanding, transformational adaptation includes “three classes of adaptations”: larger scale, novelty to a region, or shifting of locations. This notion can be expanded to the reorganisation of governance structures and reorientation as a reconfiguration of social values and relations (Few et al., 2017). In other studies, the transformation itself either can be directed, or rather gradual, or abrupt (Elmqvist et al., 2019).

Due to blurred definitions, it has become difficult to clearly delineate adaptation, adjustment, and transformation since adaptation can be of adjustable or transformative character. Nonetheless, many authors agree that transformative adaptation is a reconsideration of paradigms, assumptions, deeply held beliefs, and the way humans are relating to nature (O’Brien, 2012; Pelling et al., 2015; Schipper, 2007). This includes an overcoming of conceptual dichotomies regarding how we study human-environment relations, acknowledging the complex, entangled character of the current socio-ecological crises and ‘socio-natures’ (Nightingale, 2018, 2020) as well as relational perspectives on risk (Bohlo and Corvellec, 2011) and collaborative risk governance (Bendz and Boholm, 2019; Boholm and Prutzer, 2017). This angle of more critical research on transformative adaptation also requires a thorough analysis of justice aspects regarding transformation, and of power relations that impede transformative action, including manifold structural barriers (Brand, 2017; Nightingale et al., 2020).

In summary, there is a wide variety of concepts, definitions, and understandings, some of which oppose each other whilst others appear as too complicated (or even complex) to be brought into practice. We thus propose the following working definitions (Table 3). As far as the term ‘change’ is concerned, we use it in the sense of the Oxford dictionary as “the act or result of something becoming different”, e.g., for any type of modification of human interaction with natural or other systems.

The aim of transformation research is to understand systemic change, whereas transformative action attempts to deliberately facilitate transformation. While conceptual studies exist, including suggestions to combine conceptualisation with an application (Turnheim et al., 2015), empirical studies are still lacking. What is left open for discussion at this stage is whether the separations of terms cited here are convincing enough to, for example, analyse whether actions as described in case studies are rather adaptive, adjustable, or transformative? However, since there are major overlaps between adaptation and transformation (Table 3), that seem difficult to disentangle, the case study analysis focuses on separating adjustments and transformations.

### 2.2. Theoretical frameworks on resilience and disaster risk reduction in relation to transformation

In addition to the definitions mentioned above, several other conceptual and theoretical frameworks explicitly include transformation in a number of ways. The Disaster Resilience Integrated Framework for Transformation (DRIFT), for instance, attempts to operationalize disaster resilience to improve practical applications of the resilience concept. According to the authors, transformative capacity – besides preventive, anticipative, absorptive, and adaptive capacity – is one of the capacities needed to achieve resilience (Manyena et al., 2019). These capacities serve to inform an “increased understanding of risk drivers”, based on changes that include a “bounce back” or a “bounce forward”. In this sense, this approach moderates between traditional and recent perspectives on resilience. Some authors (Elmqvist et al., 2019; Sachs et al., 2019) also link transformation to resilience, but at the same time to sustainability. Arguing that there is a lack of clarity for these three concepts, the authors propose a framework that conceptualizes them as complementary elements in complex adaptive systems. Transformation is either described as direct, i.e., proactive actions such as the implementation of new technologies to meet new demands or to get out of lock-ins, or abrupt, i.e. fundamental structural changes with impacts across scales. Both types of transformation are inherently intertwined with sustainability, and together they determine the resilience of a system. From an actor perspective, some argue that transformation is different from resistance and consists of disruptions of the system, intense interactions between actors, social learning and external actors being able to influence the system (Gibson et al., 2016). Another conceptual framework identified “three opportunities that have the potential to lead to transformation”, trade-offs between development and disaster risk decision-making, equitable resilience, and adaptive governance (Thomalla et al., 2018). Transformation and ‘transformationative development pathways’ provide an opportunity to better link disaster risk reduction and development objectives as they are “challenging dominant values and goals in current development practice, examining the underlying failures of development and DRR, and calling for radical policy changes” (Thomalla et al., 2018). It appears to be based on or related to previous work on such trade-offs that captures a greater variety of aspects (Tuhanen et al., 2018).

Livelihood frameworks are expanded on the notion of transformation by e.g., linking transformation of processes and structure generally to all capitals, for example, in relation to household vulnerability in volcanic risk areas (Dewanti et al., 2019). In other conceptual frameworks, transformation is a sub-component, for example, within ‘opportunities’ that arise within natural disasters as a development opportunity (Bánóczi

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<th>Table 3</th>
<th>Summary and working definitions of adaptation, adjustment, change, and transformation.</th>
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<tr>
<td><strong>Adaptation</strong></td>
<td>An adjustment is a reaction to a trigger of any kind, e.g., natural hazards. The reaction can consist of a set of measures (but not necessarily) and has the goal to improve a given situation. For example, the concept of integral risk management is an adjustment: It’s a set of measures to improve the risk situation in a given area.</td>
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<tr>
<td><strong>Transformation</strong></td>
<td>A complete change in a system, e.g., by crossing tipping points and thereby reaching a new system state, or by a deliberate as well as unintentional change of structure. Transformation is the superlative of change. Transformation can occur on different spatial and temporal scales, i.e., it can be comparatively sudden or incremental (though this depends on the standard of comparison: Do we compare it to human life-spans or rather life-spans of civilisations? A “sudden” change for us as humans might be an incremental change for a civilisation). Transformation is limited in time comparable (but not equal) to a revolution. Diagnostic examples:</td>
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<tr>
<td>• Reorganisation of governance structures or a reconfiguration of social values and beliefs (Kates et al., 2012)</td>
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In this sense, transformations are seen in a line of the process from economic growth to development. While this presents by no means a comprehensive overview of the use of transformation in recent conceptual frameworks developed in the fields of disaster risk, sustainability, and resilience research, it gives a good impression of the various ways in which the term is currently used. In addition, this brief summary reveals that a common understanding of transformation only seems to exist along distinct lines, often continuing pre-existing ‘schools of thought’ or theoretical frameworks such as the (ecosystem-related) resilience concept or livelihood approaches.

2.3. Conceptual framework to be used in this paper

Against the backdrop of the existing literature presented above, this paper attempts to identify and integrate aspects of adjustments, and transformation in a conceptual framework that will guide the analysis in an exploratory approach, which will be tested against insights from empirical examples. While these examples were conducted independently of this framework, they can help to identify transformation aspects, and separate them from adjustments (cf. Table 3).

The framework used (Fig. 1) separates the observed process into three main areas: (1) Triggers (natural hazards or social activities as initiating events or processes that induce some form of change – whether this change will be adjusting or transformative will be analysed per case example using the criteria identified in Tables 1 and 2). (2) Interventions (human-induced change processes – when this change only occurs (and continues to occur) as a reaction to a natural hazard trigger, it characterises adjustment, not transformation, and (3) Adjustment (human reactions in dealing with the change process in the first two areas – when these reactions are an endpoint, it resembles adjustments, but when it triggers additional reactions, it resembles transformation). The framework can help to identify fundamental changes (Table 1) and also separate them from mere incremental adaptations.

This explanatory framework intends to illustrate key aspects and components that help to better identify adjustments and transformations. Four key components are separated to study their role in the case studies, and to analyse how they interact in adjustments, transformations, or all. Any change is a potential trigger for adaptation, which in turn can consist of adjustments or transformations. One example of a typical process pathway would be a trigger moment such as an earthquake or a revolution, resulting in humanitarian aid in these reactions are an endpoint, it resembles adjustments, but when it continues to occur) as a reaction to a natural hazard trigger, it characterises adjustment, not transformation, and (3) Adjustment (human reactions in dealing with the change process in the first two areas – when these reactions are an endpoint, it resembles adjustments, but when it triggers additional reactions, it resembles transformation). The framework can help to identify fundamental changes (Table 1) and also separate them from mere incremental adaptations.

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3. Examples

The examples were selected to analyse aspects of change and discuss whether they may represent adjustment, or transformation.

From a methodological viewpoint, the relatively short descriptive case studies in sum are meant to showcase the diversity of types and processes of change. Descriptive case studies may also include some statements and findings on causal relationships (Gerring, 2017, p. 56). In this vein, the following examples do not claim to provide a full causal comparative case study design (e.g., “most similar” or “most different” exploratory or estimating causal case study designs, Gerring, 2017, p. 41). As stated in the introduction, the aim of this paper is to offer a range of perspectives and illustrations, but not to generalise from disjunct examples.

The following case studies focus explicitly on our key interest, i.e. aspects of adjustment, and transformation with the aim to distinguish them in practical terms. The case studies are then analysed to conclude whether they represent adjustment or transformation. The examples are from different countries and contexts from Africa, Asia, Europe, and Oceania to provide a wide context as well as cultural variety. All examples are related to water, be it riverine, pluvial or coastal floods, sea-level rise, or water scarcity. Many examples are related to climate change such as riverine floods, sea-level rise or drought.

3.1. Example: Flood risk management and governance processes in Austria

In Austria, the development and introduction of environmental and river flood legislation have led to a process of institutional and social change (Papathoma-Köhle et al., 2021). This includes more than one change since the legislation does not only determine ‘where we build but also how’ (Attems et al., 2020; Holub et al., 2012). During the 1970s, legislation in Austria changed as a response to major flood losses (Keiler and Fuchs, 2018). As such, the Austrian Forest Law (1975) introduced hazard mapping in large areas, defining “red” and “yellow” zones with restrictions for land development, namely the refusal of building permissions in areas of considerable exposure (Republik, 1975). This legislation changed the way land use was regulated by governmental institutions on various levels. Once the laws came into power, hazard exposure was acknowledged for the first time, which allowed for the implementation of measures to reduce exposure and avoid future losses. In the Federal Water Act (1985), public subsidies for technical mitigation measures are addressed (Republik, 1985). This act changed the
ways how government subsidies were distributed to support technical flood mitigation at the local level. The main decision rule according to the 1985 Water Act was cost-efficiency, changing the governmental spending of public money.

In Austria, the market penetration of private property insurance is exceptionally low (Thaler and Fuchs, 2020), mainly because there is an option to be compensated through the disaster fund, regularised by the Federal Act related to the Disaster Fund of 1966 (Republik, 1966). The Federal Act is the legal basis for providing national resources for (a) preventive actions to construct and maintain torrent and avalanche control measures, and (b) financial support for the federal states to enable them to compensate individuals and private enterprises for losses due to natural hazards in Austria (Holub and Fuchs, 2009). To finance the disaster fund, tied surcharges were put on income, wage, corporate taxes, and taxes on capital yields. Following several amendments, the legal act from 1966 was revised by the so-called Federal Act related to the Disaster Fund of 1996 (Republik, 1996). Since this public fund turned out to be insufficient to subside the 2005 flood losses in Austria, a specific law on loss compensation of these flood events was issued in 2005 (Republik, 2005).

Finally, in 2007 the European Flood Directive can be seen as another example of change in natural hazard risk management; the EU member states are required to implement flood hazard and risk maps as well as flood risk management plans (Commission of the European Communities, 2007). Transformation, in this case, is the shift in responsibility-sharing between public and private actors, since information of better quality is made available for affected citizens to inform themselves about possible exposure of their properties to flood hazards. As such, this development is linked to the emergence of new management approaches within flood risk management, which consider not only governmentally-driven mitigation measures but also measures to manage the consequences of flooding (Rauter et al., 2020), including the question of relocation (Thaler and Fuchs, 2020). While the legislative process was triggered top-down, it has induced a number of bottom-up feedbacks and social reconfigurations of responsibility-sharing.

It is admitted that there exists other or even contradictory evidence on accepting responsibility-sharing, for example on accepting risk zonation (Thaler and Fuchs, 2020). Risk zonation as such is a useful example of an intervention that can mitigate flood risk, or even trigger novel discussions about necessary changes. Hence, the example of Austria shows the potential of legislative frameworks for triggering a change in natural hazard management, either by intention or indirectly (Fig. 2) and therefore unintentionedly by changing e.g., rules for subsidising losses or for land-use planning. Aspects of change of this example are schematically summarised in Fig. 2.

Regarding the question of which aspects of those changes represent adjustment or transformation, some observations are made, based on the working definitions (Table 3). The example represents adjustments where the major part of human-induced interventions (middle box, Fig. 2) represent small changes to improve river flood risk. These adjustments have triggered additional reactions of other actor groups affected by both natural hazards and the interventions taken against them. It is an example of institutional change that eventually leads to social change. Risk zonation is a form of a planned transformation of the built environment.

‘Willingness to relocate’ (Fig. 2) is an attitude that can lead to decisions of relocation. It is also a psychological adaptation when people who were not willing to relocate react to the presence of new triggering events and / or interventions, i.e., a change in the surrounding conditions. In the line of community resilience, engagement and social actions are regarded as key elements. This diagram illustrates that we do not only consider physical but also social adjustments. Social adjustments can result in physical adjustments such as house construction, but physical realities such as house abandonment or demolishment also influence or enable interventions such as risk zonation enforcement. Risk zonation then in turn reduces exposure to flooding, but also reduces the flood hazard when soil sealing is removed and removed houses do not hamper water discharge from rivers anymore.

3.2. Example: Relocation in Indonesia

Relocation is a commonly expected process in the way society adjusts to natural hazards such as floods (Kox, 2016). It is assumed that firms will directly address current and future losses and seek to maintain their operations by investing in a new, safer plant location to take advantage of the potential long-term benefits of adaptation (Linneweber et al., 2012). However, an example of highly flood-prone manufacturing firms in Jakarta and Semarang shows that firms refuse to relocate, although the current urban flood mitigation policy in both cities seeks to relocate businesses from flood-prone areas (Neise and Diez, 2019). Fig. 3 illustrates the relations between introduced incentives and measures with factors such as willingness to relocate. Large tidal and pluvial flood
events are barely motivating firms to relocate. Due to neighbourhood attachment and high investment costs, small- and medium-sized enterprises (SMEs) in particular, prefer to stay at their current location (Neise and Diez, 2019). Instead of relocating, SMEs are rather willing to co-finance flood risk reduction measures (e.g., a polder system) that can protect their business and the community from flooding (Neise et al., 2021). The example shows that top-down-approaches do not necessarily result in the anticipated transformation, in this case in the sense of relocation. Still, at a closer look, the local firms have not only adjusted the conditions for their workers but the workers have also become engaged in dealing with long-term changes in their environment. However, since both groups decided to stay and sustain their situation, without major reconfigurations of their social relations or values, it this is an example for adjustment, although transformation might have been the goal. The example illustrates, however, that the socio-political discourse as to whether relocation is expedient is an active consideration about transformation as an option, even when the idea is postponed for the moment.

The findings also suggest that transformative adaptation should take into account socio-economic ties, for instance, between firms and their employees or customers, which could be broken by relocation (IPCC, 2019b). Transformation hence, may also disrupt social configurations and must not only be considered positive in all cases (Nikuze et al., 2019; Patel et al., 2015).

### 3.3. Example: A radical questioning of the current nation-state system in Oceania

In Oceania, low-lying atoll island states suffer from colonial legacy such as the destruction of local trade, governance and belief systems and, increasingly, from the effects of climate change. Kiribati is one of these countries and it is described as being most vulnerable and exposed to the effects of climate change, such as stronger and more frequent storm tides, coastal erosion, and sea-level rise (Nurse et al., 2014). Kiribati is an atoll island nation state of 33 islands that are scattered along the Equator and spread across approximately 3.5 million square kilometres of ocean. It has around 118,000 inhabitants. South Tarawa is the capital and largest urban centre of Kiribati. It is one of the densest urban agglomerations in the Pacific, if not the world (population approximately 56,000) (World Bank, 2021). In the longer term, Kiribati might even lose its inhabitable land due to sea-level rise (Risse, 2008). Motivated by a call for climate justice and the general public rejection of the refugee status, former President Tong created the Migrate With Dignity Strategy (MWD) during his Presidency (2003–2016). In addition to circular work programmes with Australia, New Zealand, and other countries there are also aspects of MWD that stimulate a new way of thinking and do not fit into the national state order as we know it. One example is the purchase of land, which has been negotiated with the government of Fiji in 2012, so that one day communities from Kiribati could settle there and that could serve to enhance food security in Kiribati on a short- to midterm. The resettlement of entire communities will also serve to preserve the culture of the I-Kiribati (the people from Kiribati) in the future. In addition, Pelenise Alofa, representative of the Kiribati Climate Action Network (KiriCan), has asked for a new status of citizenship for future climate migrants before the UN Human Rights Council in Geneva in 2015. She envisions a new status for climate migrants attributed with environmental or climate citizenship as a possibility to settle as a community or individually. The status as environmental or climate citizen would entail cultural rights and minority rights in the host country (Klepp, 2018; Klepp and Herbeck, 2016). The example of Kiribati shows that escaping the hazard is not solved by top-down regulated relocation alone but could come with major political, economic, and societal reconfigurations. For example, the awareness about the need to protect culture and values or an environmental citizenship identity. This example hence exhibits aspects of transformation (Fig. 4). Envisioning the relocation of a whole country and its culture certainly is an example of major reconfigurations that do involve both reorganisation of society as well as the adaptation to a new environmental setting with novel hazards and conditions. It also does involve not only one actor group planning the migration strategy but all actors involved in one country. International negotiation processes with potential host countries are evolving against the background of the effects of climate change that become more severe in atoll island countries. These processes appear to have gone on for quite some time, in which several reconfigurations of political agendas and reactions of society have already occurred. The case of Kiribati may therefore be one of an ongoing transformation of the mindsets of people and governments, and can hence not be measured by relocation alone. This is even more the case, as the current President, Taneti Maamau, follows a different agenda than Anote Tong. He considers the migration policies that Tong introduced and that included the long-term relocation of the whole population as too pessimistic (Hermann and Kempf, 2019). President Maamau, on the contrary, supports mainly in situ adaptation such as land reclamation in the capital South Tarawa (e.g., within the Temaikau Adaptation Project) and the building of sea walls, as it was already carried out under the large scale Kiribati Adaptation Project financed by the World bank (2003–2018). The adaptation strategy of the current government can be found in the

![Fig. 3. Change processes and feedback-loops in the example in Indonesia.](image-url)
development programme *Kiribati 20-Year Vision 2016–2036* (Government of Kiribati, 2016). Nonetheless, the unique policies of Anote Tong, such as MWD, the purchase of land in Fiji and the consideration of new status of citizenship for climate migrants are still widely discussed in the Pacific and elsewhere. These processes are only just at the beginning and thinking “out of the box” will be decisive for just and transformative adaptation measures.

### 3.4. Example: Behavioural change in response to Cape Town’s water crisis

Cape Town is a global hotspot of water scarcity (Burek et al., 2016). The ratio between the city’s freshwater supply and demand has been exacerbated for years and results from climatic and human-induced pressure exacerbated by an ineffective water system and inefficient water use (Ziervogel, 2019). In response to increased pressure, the city’s government has engaged in sporadic adaptation measures, dominated by centralized, technical solutions, such as the extension of storage dams (City of Cape Town, 2018a). Despite the manifestation of several droughts in past decades, population, economy, and environment were not severely impacted. This led to a low-risk awareness and sense of security as well as a low valuation of water among citizens. Responsibilities for water supply and risk management were attributed to the authorities, which partly results from legal frameworks guaranteeing water provision (Assembly, 1996) and prohibiting alternative water sources such as domestic rainwater harvesting (DRWH) (City of Cape Town, 2018a; b). The 2016–2018 water crisis, however, induced some substantive behavioural changes that can be considered transformational. Imposed restrictions and the announcement of “Day Zero” substantially increased the perception of water scarcity as a threat. As they realized that government responses could not sufficiently reduce these perceived threats, Capetonians attributed responsibilities for responding to the aggravating water scarcity to themselves. Households across different socio-economic groups started to significantly reduce their water use (Visser and Bruhl, 2018), which also led to an increased valuation of water. In turn, the increased perceived value of water also reduced some of the obstacles for engaging in alternative water resources such as DRWH. Although not being considered as a viable option for a long time, DRWH gained significant value to households. This went beyond economic aspects as people were mainly concerned about their well-being. The provision of an emergency source in case of “Day Zero” or of additional water for restricted leisure activities such as filling pools or watering gardens are just two of these multiple non-monetary benefits of DRWH.

The outlined mind-shift encompasses the majority of the population and is assumed to have substantial and perpetual character. Furthermore, the newly established values, beliefs, and norms on water use tackled some of the root causes of vulnerability to water scarcity. Therefore, it can be considered as transformative in multiple of the above-outlined dimensions, since it triggered a fundamental change of behaviour and awareness of the people affected as well as those in the authorities (Fig. 5).

### 4. Discussion

This paper investigates the difference between adjustment, and transformation in the context of natural hazards and climate change. The case study analysis mainly investigates the main differences between adjustment and transformation, but also covers adaptation in the state of the art section and discussion, since it is closely related. The framework suggested in Fig. 1 contains a conceptual separation of changes into several processes that interact, to help identify differences between those terms. However, several aspects need to be discussed further.

#### 4.1. Advancing the framework based on the case example insights

The examples have been used to investigate if the changes described exhibit adjustment or transformation. As a major constraint, the observation periods in all cases are rather short, and, as such, the future development of the respective cases remains an open question. Scale – temporal as well as spatial – seems to be an important aspect to consider. For example, relocations can be seen as a transformation for a given village, but they might be an adjustment on a national scale. It is thus important to be clear about the scale of a given study. As we have tried to show, adjustment means a small change in a system with the goal to improve a given situation. Transformation, in contrast is a systemic change, and in most cases this will imply the change of structure, as well as cascading effects and feedbacks.

In the case of South Africa, it was very useful to not only adjust the behaviour of some, but of many stakeholders. This adjustment took more than just structural changes in administration and communication.
strategies, it involved a change in mindsets. However, as such examples are very context-specific a selection of one example per region cannot be used to generalise for other countries and contexts. In contrast, our purpose was to identify a certain variety of aspects of change, with similar contexts and questions on water-related hazards and risk governance aspects. Many of them seem to be related to structural measures such as relocation as well and non-structural measures such as behaviour. The findings of the examples in addition to the aspects of transformation from common definitions (Section 2) can be summarized, and also compared to the initial framework presented in Section 2.3. The comparison reveals a much more detailed break-up of cascades and feedback loops, and especially show an evolution of adjustments and local transformations towards a national transformation. The risk zonation example from Austria itself is an outcome of a transformation process, preceded by a changed perception and risk tolerance towards flood hazards. Secondary amplifiers (Kasperson et al., 1988) such as taxation and willingness to relocate, show that this transformation process is still ongoing and evolving. Transformation, hence, is an evolution consisting of incremental fundamental system changes that can turn out positively or negatively.

4.2. Informing existing frameworks and integration

Conceptual frameworks used in transformation research typically seem to include a timeline, or trajectories, with different pathways or outcomes. These presentations seem to be related to previous graphical representations of mathematical curves, longitudinal wave models of development phases (Kondratieff, 1935), resilience models in ecosystem research, engineering, event, or fault-tree models, including variants of scenario funnels or bow-tie models, or project management cycles (Talbot and Jakeman, 2009).

Recent research has seen a plethora in the usage of the explicit term ‘transformation’, especially in urban studies concerning natural hazards, sustainability, and/or resilience (Matyas and Pelling, 2015; Pelling, 2010; Satterthwaite and Dodman, 2013). Still, empirical studies within disaster risk are lacking, which in turn has motivated this study. While a number of theoretical frameworks have been suggested, especially within the realm of climate change adaptation, disaster risk science aspects are only partly included. Closely linked to this upcoming research nexus the concept of “pathways” gained traction among scholars as well as policy and decision-makers (Gibson et al., 2016; Rosenzweig and Solecki, 2018; Wise et al., 2014). Here, several approaches have emerged that often cover uncertainty concerning climate change developments, such as ‘dynamic adaptive policy pathways’ (Haasnoot et al., 2013; Lawrence and Haasnoot, 2017), or ‘shared socioeconomic pathways’ (O’Neill et al., 2014). Frameworks displaying such pathways (as in the literature covered here) often do not explicitly depict feedback loops or detail them further. However, multi-risk studies with multi-linear development paths need not only to consider one-directional cascading effects but also interdependencies and hence, feedback loops.

Quite often the changes in disaster risk management observed, in reality, are related to large events that triggered a political decision, such as has been argued for the European Floods Directive (Fuchs et al., 2017). To overcome this reactive approach, the call for proactive and risk-informed disaster risk reduction (United Nations, 2015) has to be supported by more explicit guiding frameworks detailing transformation with feedback loops. The notion of feedback loops or bidirectional interdependencies is not novel itself, as it had already been outlined explicitly in concepts and frameworks of (general) system theory and system dynamics (Chorley and Kennedy, 1971). However, recent developments in disaster risk science have underlined the importance of observing feedback loops further, such as cascading effects and interdependencies of society with critical infrastructure services (Pescaroli and Alexander, 2015). It is therefore necessary to provide frameworks that integrate such components identified in this line of critical infrastructure research with the frameworks of transformations and pathways emerging in climate change debates.

To add another aspect, transformation research concerning climate change and disaster risk reduction needs to capture not only development paths in the aftermath but also new emerging trends. The European Commission, for example, currently fosters actions and research on resilience in relation to so-called megatrends such as climate change, demographic change, migration, health and others (European, 2020). Trends, megatrends in relation to climate change, natural hazards or disaster risk also are a topic in Africa (Lipper and Benton, 2020), Asia (Mukherji et al., 2018), Oceania (Hajkowicz et al., 2012), and globally (Lorenz et al., 2018). Application gaps of existing frameworks on transformation, transition or pathways as identified in the literature analysis above include.

Fig. 5. Transformation processes and feedback-loops in the example in Cape Town, South Africa.
a) Temporal stages or phases failing to separate and take up existing notions that go beyond simplistic linear models. Especially for complex adaptive systems (Gell-Mann, 1994; Gunderson and Hol- ling, 2002; Levin, 1998), time phases should include triggering phases, amplification stages of risk (Kasperson et al., 1988), sec- ondary and compounding effect phases (Zscheischler et al., 2018), process chains and cascading effects (Pescaroli and Alexander, 2015; Rinaldi et al., 2001), and feedback loops (Chorley and Kennedy, 1971).

b) While transition models focus on decision-makers, affected people often are once more included only as passive subjects under impact assessment models. The conceptual framework, however, should include people and all types of stakeholders (whole of society and all- actors approach) (Pescaroli and Alexander, 2015). It should be sensitive to various ontological backgrounds and to different cultural, political, and social contexts (Wisner et al., 2004). This range of different social and cultural contexts also suggests a wider usage of interventions such as structural or non-structural risk management measures.

c) Geographic notions of space have to be included, not only as basins of attraction in a pseudo-linear representation of a timeline, but also regarding context-specific place-based features such as local spatial conditions, and interdependencies between macro-meso and micro- levels (Tümer et al., 2003). Relocation is one example where macro-level conditions of climate change interact with place-based conditions that may render people unsafe, yet at the micro-level people make decisions to still reject relocation. We recommend future conceptual frameworks of transformation to integrate these aspects.

5. Conclusion

As this study shows there is a rich conceptual debate and scientific discussion around the term transformation and related concepts like adjustment and adaptation. Nonetheless or even because of this richness, definitions vary and especially empirically grounded reflections are lacking. Against this background, this paper adopts an empirical perspective on transformation by asking which actions and processes truly lead to transformation on the ground with the aim to complement the strong conceptual debate on this topic. In addition, the findings are meant to support decision-making by risk managers and stakeholders addressing natural hazards related to climate change. For this, the study provides a discussion and clarification of the terminology, a working framework to differentiate triggers, interventions, adjustments and transformation illustrated through multiple case studies. The latter facilitate the understanding of the different facets of change on the ground, be it adjustments, adaptations or transformations, which can be useful for guiding decision-making for short, or long-term land use and management planning, acceptance and mainstreaming of measures being taken. In particular, we suggest that the findings may guide various actors who are involved in decision-making related to climate risk governance such as planners, emergency and disaster managers as well as the people affected. The examples presented show details of triggers, and typical interventions taken by individuals, organizations, governments and the private sector to cope with, adjust or transform. They showcase that typical disaster risk governance interventions such as communication and awareness-raising, the introduction of new reg- ulations and legislation as well as behavioural measures or relocation can result in transformative changes, depending on specific contextual conditions as well as their uptake and effectiveness. All in all, the study including the case studies highlight the diversity of the portfolio for transformative measures that facilitate prevention and long-term planning for sustainable development.

However, to what extent the transformative potential of these measures can be tapped remains partly unclear and lacking conceptual an- alyses continue to hinder effective, in-depth empirical research that could help facilitate existing barriers. The case study on Cape Town illus- trates one of these potential barriers: Here, the implementation of water protection measures alone will not be able to solve future water shortages. Only if additional measures succeed in triggering human behavioural change, transformation towards water security can be achieved. Against this background, it could be concluded that human behavioural change seems to be the most pressing constraint to trans- formation capacity. The interaction between structural behavioural changes and other instruments (financial, physical, regulatory) are important aspects to further analyse transformation. Studies conducted in different parts of the world provide elements of analysis that can be transferred to other areas. Transformation is a current trend in conceptu- alising long-term studies; in order to make it useful for monitoring and empirical application, it will be helpful to gain a common under- standing of definitions and conceptual frameworks of analysis.

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