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ORIGINAL ARTICLE

Flexibility for intergenerational justice in climate resilience decision-making: an application on sea-level rise in the Netherlands

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Abstract

To adapt to a changing climate, decision-makers design, evaluate, and implement measures that have an implication of justice on citizens in the present and well into the future. Decision-makers are often required to make decisions without certainty of the consequences and understanding their effects on intergenerational justice. Thus, managing the impacts of climate change requires novel decision-aiding approaches that consider climate impacts' temporal and spatial heterogeneity and the uncertainty in climate predictions, preferences, and values. We reviewed the literature on the extent to which principles of intergenerational justice—conservation of options and resources for future generations—have been integrated to traditional approaches in climate resilience decision-making. We explore the extent to which flexibility, i.e., the conservation and expansion of options in subsequent decision periods, can contribute to upholding the principles of intergenerational justice under uncertainty. We illustrate the approach in the case of the Delta Programme in the Netherlands, a complex system designed to protect against sea-level rise (SLR). Designing adaptation strategies to SLR with flexibility as a core concept brings significant advantages in circumstances of uncertainty. The conservation of options in flexible pathways, in this case, contributes to the principles of intergenerational justice. Our civilization's long-term sustainability and survival may depend on the extent to which individuals can see beyond their gains and toward the gains of the collective society at an intergenerational scale.

Keywords Decision-aiding approaches · Adaptive pathways · Climate change · Sea-level rise

Introduction

Justice scholars have raised relevant questions about the moral obligations of current generations to future generations; this is referred to as intergenerational justice (Gardiner 2006a; Tremmel 2006). These normative considerations include the preservation of options, resources, and opportunities for future generations so they may realize their aspirations (Gosseries 2008; Schuppert 2011; Sanklecha 2017). The definition, explanation, and advancement of the rights and opportunities of future generations are at the core of intergenerational justice. Although much of the focus of intergenerational justice has been on climate change mitigation (Caney 2009; Schuppert 2011; McInerney et al. 2012), decision-aiding approaches (DAAs) in climate adaptation and resilience have been increasingly focused on intergenerational justice. Specifically, there is a growing interest in developing more concrete approaches to evaluate the effects of adaptation actions on intergenerational justice.

The effect of climate change on the social and natural systems in the biosphere is increasingly influencing the way decision-makers design, assess, and implement measures to reduce risks for present and future generations (Bierbaum et al. 2013; Baird et al. 2014). Inaction or short-sighted actions designed to adapt to current and expected changes may result in consequences that jeopardize the security and livelihood of future generations (Roemer 2011; McInerney et al. 2012). The DAAs available to decision-makers are unable to accurately predict the long-term

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consequences of adaptation options (Merkhofer 2012). The long-term values and preferences of members of society cannot be easily defined, given that it is impossible to reliably estimate what future unborn generations will value. Moreover, the consequences of adaptation options play out in highly complex systems that are not fully understood and thus ignore possible cascading effects (Underdal 2010). As such, ideal DAAs must also account for the possible changes in social values and the unanticipated effects of adaptation actions on intergenerational justice (Newell et al. 2020).

There is a wealth of decision theory to draw from concerning uncertainty (Benjaafar et al. 1995; Comes et al. 2011; Walker et al. 2013; Malekpour et al. 2020). In decision-making under Knightian *uncertainty* (Knight 1921), unlike under probabilistic uncertainty (i.e., Knightian *risk*), the probabilities of the consequences of actions are unknown. Thus, estimating the expected value of specific adaptation actions is practically impossible. In such circumstances, it is challenging to assess the effect of decisions on future generations (Thiery et al. 2021). Flexibility has been proposed as a principle able to address uncertainty in decision-making. We draw from this flexibility literature to elaborate an approach for addressing the uncertainty inherent in the climate problem by keeping multiple options open for future generations in anticipation of unexpected changes and the emergence of new information (Benjaafar et al. 1995; de Haan et al. 2011; Walker et al. 2013; Kwakkel et al. 2015). Decision-making that employs the flexibility principle will likely reduce irreversible loss and preserve the present and future people's fundamental rights and freedoms. Thus, there is a substantive theoretical link between flexibility and climate change decision-making. However, it is as yet unknown whether the concept of flexibility can meet the requirements of intergenerational justice. We expand on the contribution of flexibility in decision-making under uncertainty to analyze its use in the context of intergenerational justice. We illustrate the approach in the case of the Delta Programme in the Netherlands, a complex system designed to protect against sea-level rise (SLR). Designing adaptation strategies to SLR with flexibility as a core concept brings significant advantages in circumstances of uncertainty. The conservation of options in flexible pathways, in this case, contributes to the principles of intergenerational justice.

This article is structured in the following way. First, we discuss background literature on intergenerational justice. Second, we discuss the limitations of cost–benefit analysis for climate resilience decision-making. Third, we explore the role of *flexibility* in supporting *intergenerational justice* principles in climate adaptation. Fourth, we discuss an illustrative case study of flexible climate adaptation pathways of the Dutch Delta Programme, analyzed through the lens of intergenerational justice. Next, we follow with a discussion of how flexibility can be helpful in justice-based decision-making. Lastly, we provide closing remarks and directions for future research.

Intergenerational justice and climate change

To speak of the application of justice between generations is to speak of intergenerational justice. Justice is a broad concept with a long history in moral philosophy literature (for an in-depth review, see Miller 2021). Here, we draw from a well-established conception of justice as fairness (Rawls 1958; Bell 2004; Caney 2005), which considers a fair distribution of benefits based on the notion of the 'original position.' In this view, all individuals are considered relevantly similar and therefore have equal claims to all benefits. Therefore, in situations of observed inequalities, a just distribution of benefits prioritizes improvements in the conditions of the worst-off individuals (Rawls 1958; Sen 2017, p 192). The 'worst-off' are disadvantaged because they do not have the same position or opportunities. Adler's (2012) prioritarian approach builds on this notion of justice and argues that a marginal improvement of well-being for a poor person is preferred over the same marginal improvement for a wealthy person, as it makes a more significant difference to the poor person's life.

In this light, intergenerational justice encompasses the distribution of benefits among individuals that exist across time (i.e., in different generations). In contrast to *intra*generational justice, which addresses spatially dispersed individuals in the present, *inter*generational justice addresses the just distribution of benefits among individuals irrespective of their time of existence (Van der Hijden et al. 2014), including the continuous and overlapping generations of the present and the future. Intergenerational justice is a temporal form of distributive justice. It cannot deal with procedural justice—fairness in and legitimacy of decision-making processes (Gardiner 2010)—as future generations do not have a voice or representation in the decision-making process in the present, which may affect their livelihoods (cf. Kamijo et al. 2017). To determine which generation is the "worst-off" requires making a moral judgment on which generation is at a disadvantage compared to others.

Today's generations already experience the intergenerational effects of climate change. People born in 2020 are highly likely to experience climate change more severely in their lifetime compared to those born in 1960 (Thiery et al. 2021). Thus, when we use the term 'future generations,' we refer to the overlapping generations alive today and yet to be born. Climate change is accelerating, and as time passes, climate-driven hazards will likely compound, thus making future generations incur higher impacts and losses. As such, intergenerational justice refers to the moral obligations of one generation to reduce the potential harm to the next generations. We draw on various definitions of intergenerational justice (Table 1 in Appendix) to argue that at least two types of goods can be preserved and transferred to future generations to satisfy the minimum requirements of intergenerational justice. The sustainable development literature has articulated the necessity for intergenerational justice

for the sustainable management of natural resources to safeguard common resources for future generations (Holden et al. 2014). Intergenerational justice seeks to expand the options available in the future through

- Conserving options, enabling future generations to make decisions based on their values, emerging information, and aspirations (Weiss 1992).
- The conservation of options comes hand in hand with the necessary resources to realize those options and protect the fundamental rights of future generations (e.g., life, food, safety, health) (Barry 1997; Karlsson 2016; Almassi 2017; Newell et al. 2020).

Climate change brings additional challenges to the conceptualization and realization of intergenerational justice, especially related to the uncertainty of climate change's magnitude, frequency, and impacts. Anticipating long-term future consequences is particularly challenging under conditions of uncertainty. As a result, when decision-makers want to prioritize principles of intergenerational justice in climate adaptation or resilience policy, they are confronted by the uncertainty of the climate problem.

Climate change exacerbates existing inequalities as poorer people are often the most vulnerable to climate change (Hallegatte et al. 2015). This *intra*generational aspect exists at different spatial scales, affecting how individuals realize justice across space and time (Jafino et al. 2021). As such, future generations born in poorer parts of the world will likely be in a worse position to respond and adapt to climate-related hazards (Thiery et al. 2021). The disproportionate distribution of cost and damages in the future will likely follow a non-linear acceleration due to the reinforcing feedback loops in the natural and socioeconomic systems (Cannone et al. 2008; Urban 2015).

Justice-based demands can be addressed through allocation schemes that consider current inequalities and prioritize improving the conditions of the worse-off (Adler 2012; Hall and Lamont 2013; Adler and Treich 2015; Ciullo et al. 2020) or through other distributive objectives (e.g., egalitarian).

In this study, we look at the extent to which decisions about investments and planning choices in resilience to climate change either advance or hinder intergenerational justice. Here, climate resilience is defined as "the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning, and transformation" (IPCC 2021). Resilience actions and policies are aimed at reducing vulnerabilities to unexpected future events. However, they can have long-term negative implications, whether they are related to financial investments (e.g., public debt), social-cultural (e.g., change in social norms), or technological lock-ins (e.g., hard flooding infrastructure) (Greener 2002). The uncertainty of these implications becomes an obstacle to understanding how intergenerational justice can be realized. Principles of intergenerational justice can extend decision-aiding approaches to enable decision-makers to preserve options and resources for future generations while adopting options under uncertainty. This perspective of climate resilience focuses on determining what actions are more likely to result in a fair intergenerational allocation scheme while considering uncertain future scenarios.

This section described our understanding of intergenerational justice and its core requirements for conserving options and resources for future generations. We frame this definition within the context of climate resilience, where the focus is on preparing for an uncertain future, where the magnitude, frequency, and impacts of climate events are difficult to anticipate. Therefore, we argue that intergenerational justice requirements must be considered in the decisions about climate change resilience.

Moving beyond cost–benefit analysis in climate resilience

Traditional decision-aiding approaches, like cost–benefit analysis (CBA), are incapable of accounting for the various factors involved in the climate change problem (Kind et al. 2017; Dennig 2018); namely, disaggregation of preferences, heterogeneous risk exposure, monetization of incommensurable goods, and principles of justice. In this section, we first discuss the limitations of CBA before offering a possible improvement for alleviating these limitations.

The best-known approach to assessing alternatives in decision-making is cost–benefit analysis (CBA), which has many well-documented limitations when applied in the context of climate change. Standard economic models adopt assumptions, such as ceteris paribus (i.e., all other things remaining constant) about non-existent or controlled changes of exogenous conditions, which often lack substantive scientific support. These approaches are based on ranking options by their net-present value using a static discount rate (Adler 2012; Dennig 2018). There are theoretical problems with the use of net-present values (Peters and Gell-Mann 2016; Peters 2019; Kwakkel 2020). Employing a static discount rate, reflecting a fixed time preference, effectively discounts the value of future benefits or costs compared to the value of present benefits. This is non-trivial when we are looking at the well-being of people affected by climate change; where the harmful effects of current emissions are likely to fall disproportionately on future generations, whereas the benefits accrue mainly in the present (Gardiner 2006b). There is the argument that future generations will be wealthier and better equipped at carrying the cost of climate adaptation. This argument implies assuming continuous economic and technological growth (Arrow et al. 1995). There are many critiques of this continuous growth assumption (Lorek and Fuchs 2013), not least when considering the projected socioeconomic

losses due to climate change (Hallegatte 2014; Moss et al. 2014). Therefore, it is difficult to defend the assumption of a static discount rate in situations where the future is unpredictable. Moreover, assumptions about the preferences of individuals are often static and ignore the evolution of preferences and values in a society, which may contribute to an additional source of uncertainty (Taebi et al. 2020).

Further critiques of CBA point to its inability to account for incommensurable goods and losses as it assumes everything can be expressed in terms of monetary value (Doorn 2018). This critique is also related to CBA's disregard for irreversible losses, for example, the permanent loss of an ecosystem that is irreplaceable in a lifetime. Criticism of CBA also comes from the environmentalist community, arguing that CBA is unequipped to evaluate climate mitigation/adaptation policies (Sunstein 2010). Some scholars have sought to address some of these concerns and developed more nuanced approaches to CBA, including a zero-discount rate (Dennig 2018) and a prioritarian social welfare function (Adler and Treich 2015). However, these approaches have limitations themselves, e.g., they operate in risk, but not in uncertainty and are not widely used in practice.

Resilience DAAs aim to increase resilience to climate change shocks or stresses in ways that account for the path dependencies of climate change (Engle et al. 2014). This requires going beyond the conventional approaches like CBA and accounting for uncertainty. We argue that DAAs in climate resilience must seek to enhance and not hinder the principles of intergenerational justice. The characteristics of the climate problem, such as the disaggregation of preferences and the changes in what society values, are assumed to be impossible to be predicted. In such circumstances of uncertainty, a better approach would be one focused on supporting the principles of intergenerational justice: the conservation of options to respond based on emerging information and the resources to realize their aspirations. The following section explores how the principle of flexibility addresses the limitations of climate resilience decision-making while contributing to intergenerational justice.

Flexibility and intergenerational justice

Intergenerational justice consists of conserving options and opportunities for future generations. Here, we discuss how the principle of flexibility contributes to intergenerational justice. Flexibility is defined here as the ability to keep options open during uncertain circumstances and use new information as it becomes available (Rosenhead 1980; Benjaafar et al. 1995). There is a range of applications of flexibility, although most prominent used in real options, it is applied in management, supply chains, product portfolios, natural resource management (Folke et al. 2005; Luthe et al. 2012; Cinner and Barnes 2019), and disaster/emergency response (Pauwels et al. 2000; De Lotto 2016). Flexibility is introduced in decision-making as a response to uncertainty (Rosenhead 1980; Pauwels et al. 2000; Walker et al. 2013; Haasnoot et al. 2013); assuming the future is unpredictable. For example, for an alternative (a_i) and a scenario (S_j), flexibility is the number of feasible and acceptable decision paths (dp_{ij}). The purpose of flexibility is to enable decision-makers to have a wide range of options to choose from in response to new emerging information related to changing conditions, social values, and other unobserved things.

When studied within the context of climate uncertainty, flexibility may be seen to have a higher benefit than the estimated benefits from any given option. This is because estimated benefits are not reliable under conditions of uncertainty. In such cases, flexibility can serve the principles of intergenerational justice in climate change in the following ways. First, flexibility contributes to the conservation or expansion of options for future generations, enabling the ability of future generations to choose for themselves based on future information. Their ability to choose can be measured as the number of available options that result from chosen options in the present (Benjaafar et al. 1995) (Fig. 1). Second, maintaining flexibility is the opposite of committing to a long-term fixed strategy that may prove ineffective to unexpected scenarios and lead to irreversible outcomes (Rosenhead 1980). As such, planning with flexibility promotes smaller, incremental, and reversible decisions as opposed to committing to a pathway that may result in negative irreversible outcomes for future generations (Doorn 2018). Third, flexibility is considered a financially sensible approach in decision-making under uncertainty, as it may result in a low-cost approach in the long term (Yzer et al. 2014).

Even though maintaining flexibility is a desirable quality of resilience decision-making under uncertainty and contributes to intergenerational justice, it does not directly address all aspects of intergenerational justice. Specifically, flexibility does not directly address the conservation of resources and opportunities required by future generations to pursue their aspirations and have a good life (Schuppert 2011; Matin et al. 2018). Thus, flexibility does not address the need for financial, political, or social resources to realize different adaptation options. However, this apparent limitation can be satisfied by the assumption

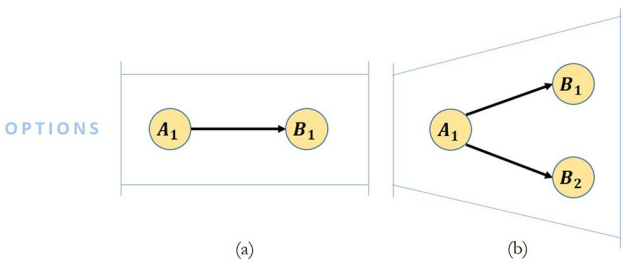

Fig. 1 Illustration of intergenerational flexibility, where generation A **a** maintains or **b** increases the number of options for generation B

that the options granted through flexible planning are feasible options if the resources necessary for its realization are available. Thus, we argue that available resources enable the options to exist. It is worth noting that even when physical resources exist, social preferences and political will do not automatically follow (Colombo and Steenbergen 2020).

Some hypothetical options may exist hidden from the perspective of decision-makers if the resources are not available to realize them. At every decision point, maintaining flexibility refers to adopting options that continue to provide a flexible choice set in the succeeding decision point. At the same time, a decision is made, i.e., an option is adopted, and resources are spent to realize that option. Thus, every decision affects the stock of resources, either limited or replenished. Overall, it can be argued that flexibility goes hand in hand with maintaining resources and that the existing resources enable the sequential nature of decision-making.

The accumulative effect of flexibility in decision-making may have lasting effects on the future. At any given decision point, the choice set and their succeeding options may enable different pathways. Some pathways may broaden the overall number of options to choose from in the future, while others may lead to fewer. In this view, even when the future is considered uncertain, flexibility itself can be considered a resource that may be conserved and passed down to future generations. Therefore, it is possible to define a-priori the possible adaptation pathways of a study area and make informed decisions that seek to conserve accumulated flexibility in the long term and not only in the immediate decision point.

Flexibility is a widely studied and applied concept, which refers to the ability to keep options open during uncertain situations and use new information as it becomes available. Therefore, flexibility is applicable in the decision context of climate change, where the spatial, temporal, and social conditions are expected to change over time and are considered uncertain. Moreover, flexibility contributes to intergenerational justice principles in the way that maintaining a wide range of choices for future decision-makers is analogous to conserving options for future generations. We argue that the conservation of options also implies the conservation of resources. A possible blind spot is that some option may exist in a hypothetical realm that may be unfeasible due to a lack of resources, which would mean flexibility is limited by resources. Therefore, the management of resources is directly related to the extent to which flexibility is possible.

Illustrative case study: Dutch Delta Programme

We draw from a real-world example to illustrate the concepts of intergenerational justice and flexibility in climate resilience decision-making. Due to the low elevation, the Netherlands is a prime example of a coastal country under stress from sea-level rise (SLR). Located in the Delta of the Rhine and the Maas rivers, around 60% of the Netherlands is vulnerable to flooding, and around one-third of its territory is under sea level (KNMI 2021). For centuries, the Dutch have reclaimed land from the sea and have built infrastructure to manage waterways and protect themselves from coastal and riverine flooding. After the disastrous floods of 1953, the first Delta Programme was implemented to protect the Dutch against flooding and reduce risk through a system of dikes, dunes, and barriers shortening the coastline (Delta Programme 2021). Although the Delta Programme has provided increased protection for the Dutch against flooding, sea level has continued to rise, and new measures are needed to safeguard the livelihood of inhabitants in the future.

This case study aims to display how the principles of intergenerational justice may be operationalized using flexibility in several decision pathways to adapt to SLR in the Dutch delta. By using methods such as the Dynamic Adaptive Policy Pathway (Haasnoot et al. 2013), decision-makers can develop pathways to chart the different policy options available to them under different scenarios. The flexibility embedded in these pathways constitutes key turning points at which adaptation strategies may be changed (Haasnoot et al. 2013, 2019; Kwakkel et al. 2015; Abel et al. 2016). For the Netherlands, a series of studies have identified four dynamic adaptive policy pathways, which may be executed in different SLR scenarios (Haasnoot et al. 2019). The adaptation strategies are summarized as follows:

- Protection-closed: protect the coast against flooding and erosion through hard or soft measures, such as flood defenses, sand nourishment, or wetlands. River arms are closed (with dams or storm surge barriers).
- Protection-open: same as protection-closed, but the rivers remain in open communication with the sea.
- Seaward: create new, higher, and seaward land located around the delta to protect against the effects of flooding.
- Moving along (or retreat): reducing the vulnerability to the consequences of a higher SLR through water or salt-tolerant land use (e.g., buildings on piles), raising of land, spatial planning, and migration.

Adaptation pathways can be represented as a decision tree to isolate the decision points along a pathway. We adapted Haasnoot's et al. (2019) pathways to a representation resembling decision trees (Fig. 2). The *x*-axis represents sea level, starting from the current sea level in 2022 to the projected increases in sea level (meters) toward the right side of the figure. As sea level increases, specific options become available, and others become unavailable or unfeasible. At any given sea level (meters), each available option is linked to a set of succeeding options. Different sea-level stages offer different adaptation options based on their preceding options. Therefore, the accumulation of costs and effort available and spent depends on the pathways taken

before arriving at a decision point. For example, at a medium to high SLR (on the right side of Fig. 2), the adaptation option of 'seaward' is available for different pathways. The difference is between a pathway that had previously chosen 'seaward' at a lower SLR and a pathway that had already implemented a 'protection-open' and 'protection-closed' strategy. Both pathways can build 'seaward,' but the process and accumulated flexibility differ depending on the pathway. As the sea level rises further, some options may become unavailable or unsuitable for implementation. Specific options may be lost if previous pathways exhausted available resources and effort.

The rate of SLR is likely to increase exponentially due to the feedback loops in the earth's natural system (e.g., melting of polar ice) (Boesch et al. 2018). In turn, decision points to maintain or change the adaptation strategy are likely to take place in increasingly shorter time windows, given that one meter of SLR in the future will happen faster than one meter of SLR now. This reduction of time intervals adds to the challenge of decision-making. The interventions required to address such hazards may become more challenging to plan and implement and possibly make some options extremely costly. This also has implications for intergenerational justice. As time passes, coming generations will experience compounding effects of accelerating SLR and thus ought to be beneficiaries of equally significant benefits of adaptation actions.

We analyzed the adaptation pathways of the Dutch Delta Programme in light of the principles of intergenerational justice. We focus on conserving options passed down to future generations facing sea-level rise (i.e., flexibility). As we have established earlier, conserving flexibility is essential to intergenerational justice. Thus, we discuss the implications of evaluating pathways based on their flexibility below. We conclude this section by reflecting on the benefits and costs of different pathways at different points throughout the pathways. Moreover, we elaborate on how flexibility responds to the principles of intergenerational justice.

Adaptation pathways are the accumulation of adaptation options adopted along the way. We looked at the selected SLR adaptation pathways from a bird's-eye view. The protection-open strategy is the pathway with the highest cumulative flexibility in the initial stages of sea-level rise. In this strategy, several options are maintained in subsequent decision points because the sea level is currently at a manageable level. Adopting a protection-open strategy means reinforcing existing protective infrastructure and not changing adaptation strategy. By investing in enhancing current protective structures, the land and real estate that is being protected will likely increase in value; an effect that may feed into a cycle of continuously increasing valuation that could increase the incentives to continuously reinforce protective structures (i.e., contributing to getting locked into this strategy). When sea-level significantly increases, maintaining the protection-open strategy becomes unfeasible, and the option to shift to a protection-closed strategy is available. At this stage of SLR, and on this pathway, the option to pursue a seaward strategy may be lost, and the cycle of enhancing costly protection

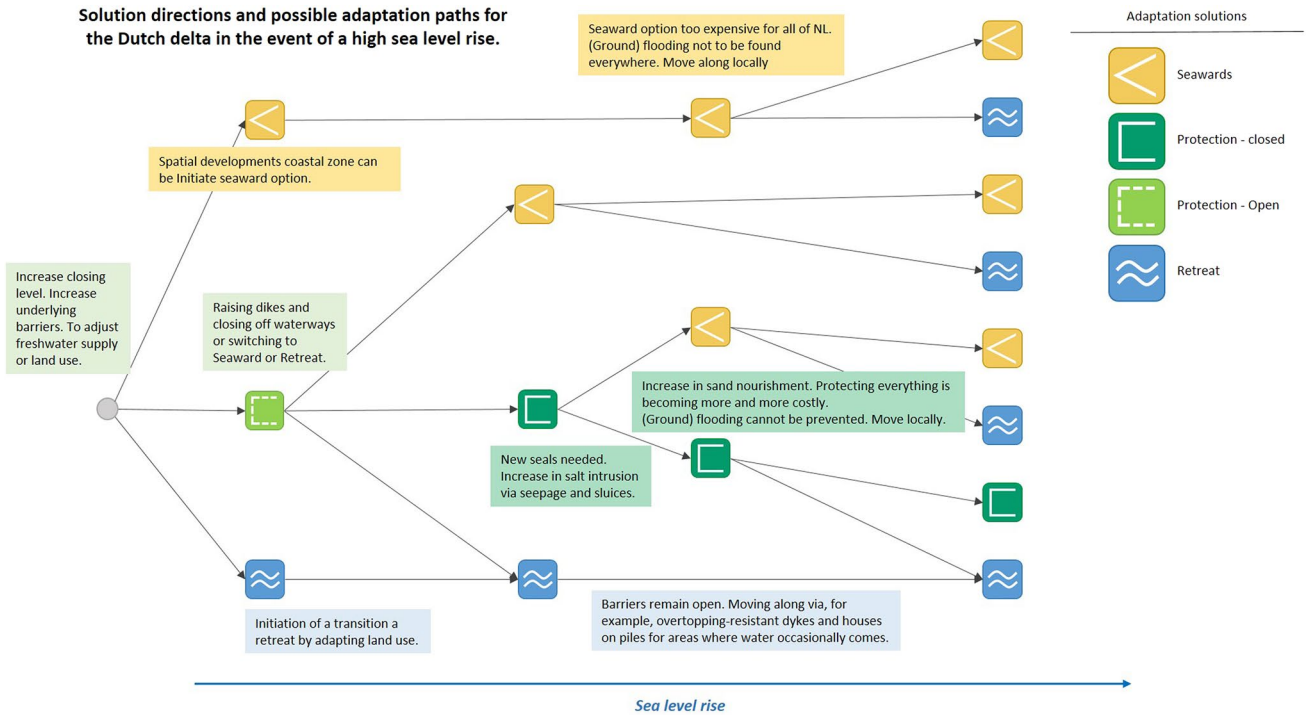

Fig. 2 Decision tree adapted from Haasnoot et al. (2019) adaptation pathways of the Dutch Delta in the event of high sea-level rise

to valuable real estate will likely continue as long as possible or until SLR is too high and ultimately reduces the available option to a moving-along (retreat) strategy.

Other adaptation pathways that begin with seaward strategy or move-along strategy at lower levels of SLR are less flexible because if adopted when sea level is low, they may result in a loss of other options; e.g., protection-open, protection-closed. These pathways are also likely to lead to lock-in. Ultimately, the policy goal is to provide protection to SLR and, in our case, to uphold the principles of intergenerational justice (i.e., through flexibility). These goals can certainly be achieved by adopting more than one pathway. As we have seen in the adaptation pathways to SLR, flexibility can vary at different stages of SLR (i.e., low, mid, high SLR), also depending on which options had been adopted in preceding decision points. As such, the decision strategy which maintains the highest number of options from the beginning is preferred as the one meeting the requirements of intergenerational justice. Moving along with water is arguably always an alternative, which is why all pathways end with the moving-along strategy. However, this alternative can have different costs at different stages of sea-level rise (i.e., midpoints), and its adoption may largely depend on the alternatives adopted at earlier stages. This can be interpreted as the possibility that maintaining or increasing flexibility can be very costly, and that following the most flexible path may result in accumulated costs that will likely be burdens on future generations. Nonetheless, the investments in flexibility can reap great future rewards if undesired scenarios materialize. Thus, flexibility is necessary but not sufficient to deliver justice to future generations.

The flexibility of adaptation pathways

The conservation of options for future generations (i.e., flexibility) is a fundamental requirement of the principles of intergenerational justice. The interpretation of flexibility may depend on its framing. We define flexibility as the expansion or restriction of options available at different stages of SLR (i.e., different scenarios). Depending on the external conditions of SLR, decision-makers have choices that are also dependent on the decisions made (options adopted) at earlier stages of SLR. The accumulative effect of decision pathways may have lasting effects on future generations. Therefore, flexibility is a resource that may be conserved and passed down to future generations. These adaptation pathways of the Dutch Delta Programme allow decision-makers to adopt options that seek to conserve accumulated flexibility in the long term and not only in the immediate decision point.

It is essential to mention that in the Dutch Delta Programme example, we consider only one dimension of scenario change: an increase in sea level. We make assumptions about the available options and pathways based on that single gauge. Considering multi-dimensional scenarios (i.e., scenarios based on more than one metric) is likely to influence the available options and pathways. However, for illustration purposes, we believe the study of flexibility can benefit from this example of the Dutch Delta Programme.

Flexibility is measured as the number of feasible options available to decision-makers when the SLR scenario changes. As current coastal and riverine flooding protections are built to withstand a specific rise in sea level, an adaptation response is needed when SLR surpasses those maximum thresholds. In the context of intergenerational justice, decision-makers ought to prefer to maintain flexibility along with rising sea levels. Even though there is a good understanding of how sea levels will increase throughout the twenty-first century, there is yet uncertainty about the exact timing and form (as well as with the potentially unobserved factors that may accelerate or decelerate SLR). Given such uncertainty, it is difficult to estimate the aggregated flexibility ahead of time. Instead, flexibility is evaluated at every decision point, where an option is adopted to consider its expected benefits and expected flexibility in the succeeding decision point. However, it is important to consider the long-term conservation of flexibility. It is also important to point out that, following this logic, maintaining flexibility may not always be the best approach in certain SLR scenarios.

Designing adaptation strategies to SLR with flexibility as a core concept brings significant advantages in circumstances of uncertainty. Keeping options open and avoiding lock-ins can be reasonable when long-term scenarios may vary. As such, flexibility responds well to the requirements of intergenerational justice, namely regarding the conservation of options and enabling future generations to make decisions based on new information and updated values. In the Dutch Delta example, new information may relate to more accurate predictions of SLR as well as a broader understanding of the feedback loops influencing SLR. An example of changing social values may be related to the degree to which society wants to alter its environment or adapt to new environmental conditions.

Discussion

Here, we have discussed the challenges for decision-making in the context of climate change with conditions of uncertainty. Intergenerational justice has become a focal point of this discussion, as climate adaptation and resilience options adopted today may have far-reaching consequences for future generations. We explored the role of flexibility in decision-making under uncertainty and elaborated on its contributions and limitations to meet the requirements of intergenerational justice. Certain decision-aiding approaches incorporate flexibility in decision domains where uncertainty is present. Using a case study, we have highlighted the relevance and consequences of flexibility in intergenerational justice. However, more can be done to develop

an operational approach to evaluate adaptation options based on their contributions to intergenerational justice.

In the Dutch Delta case, all strategies have an impact on future generations. If seen from a flexibility point of view, a high flexibility pathway would conserve a more significant number of options for future generations. The conservation of options, in this case, contributes to the principles of intergenerational justice. Committing from an early stage to some adaptation strategies, like seaward or moving-along (retreat), could lock future generations into those pathways and thus reduce flexibility and consequently limit intergenerational justice. It should be evident that flexibility is necessary, but not sufficient, to uphold our definition of intergenerational justice. The preservation of intergenerational justice goes beyond the conservation of options and must also consider the trade-offs that enable certain adaptation options. Specific adaptation actions might have a short-term positive impact, while resulting in negative outcomes in the long term, or vice versa (Juhola et al. 2016). Maladaptation can therefore manifest itself as undermining capacities or opportunities for present as well as for future adaptation (Hallegatte 2009). In this illustrative case study, we consider all available options feasible at the SLR stage in which they appear. However, it should be evident that it carries different present and future burdens and benefits even when an option is considered feasible. Moreover, as discussed above, the temporal changes of flexibility depend on both the SLR scenario and the adaptation options adopted at preceding decision points.

Without uncertainty, it can be argued that the same justice principles apply no matter whether we speak of *intra*generational or *inter*generational justice. However, uncertainty is prevalent in the climate problem, including in designing adaptation strategies to SLR. As such, DAAs that employ flexibility in circumstances of uncertainty can favor options that increase the range of options in preparation for multiple possibilities and unknown futures. In such situations, like in the case of the Dutch Delta, decision-making may be focused on upholding principles of intergenerational justice by assessing pathways based on their flexibility. The conservation of options alone does not guarantee intergenerational justice. The flexibility in options may be evaluated together with contextual factors, including cumulative resources accumulation and spending, and changes in social values.

Our findings have meaningful implications for various audiences including academic and policy-makers. The field of climate ethics has significantly increased in the last decades (Gardiner 2010; Roemer 2011; Almassi 2017), but so far, the focus has been on climate mitigation and global burden sharing for climate adaptation. This study adds to the climate justice body of literature by providing a theoretical linkage between flexibility, intergenerational justice, and climate resilience. The complexity of the climate problem means that there are conceptual challenges to the operationalization and measurement of intergenerational justice. We have provided one way to address some of the outstanding questions in the field. To policy-makers, our study provides the conceptual foundations for integrating aspects of justice in their considerations of adaptation actions. We have shown that maintaining options available can provide great benefits in the future if an undesirable scenario would materialize. However, we have stated that flexibility alone is not a sufficient criterion for achieving a fair distribution of intergenerational benefits.

At the individual level, there is a psychological tension between caring for the well-being of future generations and one's well-being (Markowitz and Shariff 2012). Today, an individual gives a higher value to benefits in the present, or even in her lifetime, compared to benefits 100 years from now. Uncertainty of the future also contributes to this time preference, as individuals reasonably prefer the known in the present to the unknown of the future. As such, employing the principles of intergenerational justice goes against some significant forces in the socioeconomic and political environment. For example, profit-seeking investments, unsustainable consumerist trends, and short-term political cycles are ingrained in daily life. Notwithstanding, long-term sustainability and the survival of our civilization may depend on the extent to which individuals can see beyond their gains and toward the gains of the collective society at the intragenerational and intergenerational scales.

Conclusion

Maintaining flexibility in adaptation options into the future responds to the fundamental requirement of intergenerational justice of conserving options for future generations. However, intergenerational justice cannot be reduced to a set of options. It must also consider complex interdependencies between the environmental and sociotechnical systems that promote or hinder the implementation and interpretation of justice by multiple generations. Moreover, society's values are likely to change and evolve into more nuanced versions of them or complete opposites. Finally, the quality of life passed down to future generations can be linked directly to the resources spent and accumulated throughout an adaptation pathway. Even though some options may be feasible, they may exist at different stages with different burdens and benefits. Notwithstanding, we conclude that flexibility may still contribute to an improved approach to climate resilience decision-making overall.

Appendix

See Table 1.

Table 1 Selected definitions of intergenerational justice

Rawls (1999)	"persons in different generations have duties and obligations to one another just as contemporaries do. The present generation cannot do as it pleases but is bound by the principles that would be chosen in the original position to define justice between persons at different moments of time."
Gardiner (2006a, 2006b)	In line with the definition of sustainability, Gardiner (2006a, b) notes that each generation tends to adopt a buck-passing behavior toward the next generations. As such, intergenerational justice can be upheld by applying the core precautionary principle
Weiss (1992)	*Conservation of options*—each generation is required to conserve the diversity of the natural and cultural resource base *Conservation of quality*—each generation is required to maintain the planet's quality of life so that it is passed on in no worse condition than the present generation received it and should be entitled to a quality of the planet comparable to the one enjoyed by the previous generation *Conservation of access*—each generation should provide its members with equitable access rights to the legacy from past generations and should conserve this access for future generations
Caney (2009)	The Scope Restricted View for time preference and discounting has three features: (1) it posits that there is a plurality of different values, (2) it affirms what I shall term the Rights Principle, and (3) that a zero pure time discount rate should be applied to the Rights Principle, but it need not be applied to other political principles or values This holds that persons have the right to protect fundamental human interests from the threats posed by dangerous climate change. Climate change jeopardizes various human rights, including, for example, (i) the right to life (since storm surges, flooding and freak weather events, and heat stress will all lead to human deaths); (ii) the right to subsistence (since the increase in temperatures, increased flooding, and rising sea levels will lead to crop failure and therefore malnutrition); (iii) the right to health (since climate change will lead to increased exposure to vector-borne diseases (like malaria) and water-borne diseases (like dengue and diarrhea); (iv) the right to property (since flooding, sea-level rise, and freak weather events may destroy people's privately and collectively owned property); and (v) the right not to be subject to enforced relocation (since sea-level rises will force inhabitants of coastal settlements or small island states to move)
Schuppert (2011)	Three conditions that meet intergenerational justice in climate change are: (i) every person's basic needs must be met (essential like water, food, health), (ii) every human has the right to a functioning environment because life depends on nature. Thus, the ability to realize their fundamental interests also depends on nature, and (3) every person has a set of fundamental economic, social and political liberties and rights that cannot be restricted for the sake of secondary concerns of intergenerational justice
Tremmel (2006, p. 189)	"The fundamental dilemma in a democratic society leads to a preference for the present and oblivion concerning the future. Hence, succeeding generations are confronted with a structural disadvantage if democracy is not improved. Generational justice affects the distribution of resources and life opportunities between generations."
Newell et al. (2020)	Future generations have the same range of options available to them as the current generation. Future generations are entitled to inherit a planet of equal quality as the current generation enjoys. Current generations must conserve the legacy or inheritance from past generations and ensure access to future generations
Almassi (2017)	Intergenerational justice can go further than compensatory and corrective forms of justice, which mainly concern righting wrongdoing, and argues for restorative justice, which in addition to acknowledging wrongdoing, is also forgiveness seeking, a behavior measured against the victim's subjectivity

Declarations

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References

Abel N, Wise RM, Colloff MJ et al (2016) Building resilient pathways to transformation when "no one is in charge": insights from Australia's Murray–Darling basin. Ecol Soc. https://doi.org/10.5751/ES-08422-210223

Adler M (2012) Well-being and fair distribution: beyond cost-benefit analysis. Oxford University Press, Oxford

Adler MD, Treich N (2015) Prioritarianism and climate change. Environ Resour Econ 62:279–308. https://doi.org/10.1007/s10640-015-9960-7

Almassi B (2017) Climate change and the need for intergenerational reparative justice. J Agric Environ Ethics 30:199–212. https://doi.org/10.1007/s10806-017-9661-z

Arrow K, Bolin B, Costanza R et al (1995) Economic growth, carrying capacity, and the environment. Ecol Econ 15:91–95. https://doi.org/10.1016/0921-8009(95)00059-3

Baird J, Plummer R, Haug C, Huitema D (2014) Learning effects of interactive decision-making processes for climate change adaptation. Glob Environ Change 27:51–63. https://doi.org/10.1016/J.GLOENVCHA.2014.04.019

Barry B (1997) Sustainability and intergenerational justice. Theoria 44:43–64. https://doi.org/10.3167/004058197783593443
Bell D (2004) Environmental justice and Rawls' difference principle. Environ Ethics 26:287–306. https://doi.org/10.5840/ENVIROETHICS200426317
Benjaafar S, Morin TL, Talavage JJ (1995) The strategic value of flexibility in sequential decision making. Eur J Oper Res 82:438–457
Bierbaum R, Smith JB, Lee A et al (2013) A comprehensive review of climate adaptation in the United States: more than before, but less than needed. Mitig Adapt Strateg Glob Change 18:361–406. https://doi.org/10.1007/s11027-012-9423-1
Boesch DF, Boicourt WC, Cullather RI et al (2018) Sea-level rise projections for Maryland 2018. University of Maryland Center for Environmental Science, Cambridge. https://ntrs.nasa.gov/api/citations/20190000403/downloads/20190000403.pdf
Caney S (2005) Cosmopolitan justice, responsibility, and global climate change. Leiden J Int Law 18:747–775. https://doi.org/10.1017/S0922156505002992
Caney S (2009) Climate change and the future: discounting for time, wealth, and risk. J Soc Philos 40:163–186
Cannone N, Diolaiuti G, Guglielmin M, Smiraglia C (2008) Accelerating climate change impacts on alpine glacier forefield ecosystems in the European Alps. Ecol Appl 18:637–648. https://doi.org/10.1890/07-1188.1
Cinner JE, Barnes ML (2019) Social dimensions of resilience in social-ecological systems. One Earth 1:51–56. https://doi.org/10.1016/J.ONEEAR.2019.08.003
Ciullo A, Kwakkel JH, De Bruijn KM et al (2020) Efficient or fair? Operationalizing ethical principles in flood risk management: a case study on the Dutch-German Rhine. Risk Anal 40:1844–1862. https://doi.org/10.1111/risa.13527
Colombo C, Steenbergen MR (2020) Heuristics and biases in political decision making. Oxf Res Encycl Polit. https://doi.org/10.1093/ACREFORE/9780190228637.013.974
Comes T, Hiete M, Wijngaards N, Schultmann F (2011) Decision maps: a framework for multi-criteria decision support under severe uncertainty. Decis Support Syst 52:108–118. https://doi.org/10.1016/j.dss.2011.05.008
de Haan J, Kwakkel JH, Walker WE et al (2011) Framing flexibility: theorising and data mining to develop a useful definition of flexibility and related concepts. Futures 43:923–933. https://doi.org/10.1016/J.FUTURES.2011.06.002
Delta Programme (2021) National Delta Programme 2021—staying on track in climate-proofing the Netherlands. Dutch Ministry of Infrastructure and Water Management, the Ministry of Agriculture, Nature and Food Quality, and the Ministry of the Interior and Kingdom Relations. https://english.deltaprogramma.nl/binaries/delta-commissioner/documenten/publications/2020/09/15/dp2021-eng-printversie/DP2021+ENG+printversie.pdf
Dennig F (2018) Climate change and the re-evaluation of cost-benefit analysis. Clim Change 151:43–54. https://doi.org/10.1007/s10584-017-2047-4
Doorn N (2018) Distributing risks: allocation principles for distributing reversible and irreversible losses. Ethics Policy Environ 21:96–109. https://doi.org/10.1080/21550085.2018.1448041
Engle NL, de Bremond A, Malone EL, Moss RH (2014) Towards a resilience indicator framework for making climate-change adaptation decisions. Mitig Adapt Strateg Glob Change 19:1295–1312. https://doi.org/10.1007/s11027-013-9475-x
Folke C, Hahn T, Olsson P, Norberg J (2005) Adaptive governance of social-ecological systems. Annu Rev Environ Resour 30:441–473. https://doi.org/10.1146/annurev.energy.30.050504.144511
Gardiner SM (2006a) A core precautionary principle. J Polit Philos 14:33–60
Gardiner SM (2006b) A perfect moral storm: climate change, intergenerational ethics and the problem of moral corruption. Environ Values 15:397–413
Gardiner SM (2010) Ethics and climate change: an introduction. Wiley Interdiscip Rev Clim Change 1:54–66. https://doi.org/10.1002/WCC.16
Gosseries A (2008) On future generations' future rights. J Polit Philos 16:446–474. https://doi.org/10.1111/J.1467-9760.2008.00323.X
Greener I (2002) Theorising path-dependency: how does history come to matter in organisations? Manag Decis 40:614–619. https://doi.org/10.1108/00251740210434007
Haasnoot M, Kwakkel JH, Walker WE, Ter Maat J (2013) Dynamic adaptive policy pathways: a method for crafting robust decisions for a deeply uncertain world. Glob Environ Change 23:485–498. https://doi.org/10.1016/j.gloenvcha.2012.12.006
Haasnoot M, Diermanse F, Kwadijk J et al (2019) Strategieën voor adaptatie aan hoge en versnelde zeespiegelstijging. Een verkenning [Strategies for Adapting to High and Accelerated Sea Level Rise: An Exploration] Deltares, Delft. https://publications.deltares.nl/11203724_004.pdf
Hall PA, Lamont M (2013) Social resilience in the neoliberal era. Cambridge University Press, New York
Hallegatte S (2009) Strategies to adapt to an uncertain climate change. Glob Environ Change 19:240–247. https://doi.org/10.1016/J.GLOENVCHA.2008.12.003
Hallegatte S (2014) Economic resilience: definition and measurement
Hallegatte S, Bangalore M, Bonzanigo L et al (2015) Shock waves: managing the impacts of climate change on poverty. The World Bank, Washington, DC
Holden E, Linnerud K, Banister D (2014) Sustainable development: our common future revisited. Glob Environ Change 26:130–139. https://doi.org/10.1016/J.GLOENVCHA.2014.04.006
IPCC (2021) Climate Change 2021: the physical science basis. Contribution of Working Group I to the sixth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge
Jafino BA, Kwakkel JH, Taebi B (2021) Enabling assessment of distributive justice through models for climate change planning: a review of recent advances and a research agenda. Wiley Interdiscip Rev Clim Change 12:e721. https://doi.org/10.1002/WCC.721
Juhola S, Glaas E, Linnér BO, Neset TS (2016) Redefining maladaptation. Environ Sci Policy 55:135–140. https://doi.org/10.1016/J.ENVSCI.2015.09.014
Kamijo Y, Komiya A, Mifune N, Saijo T (2017) Negotiating with the future: incorporating imaginary future generations into negotiations. Sustain Sci 12:409–420. https://doi.org/10.1007/S11625-016-0419-8/TABLES/8
Karlsson R (2016) Reducing asymmetries in intergenerational justice: descent from modernity or space industrialization? Organ Environ 19:233–250. https://doi.org/10.1177/1086026606288227
Kind J, Wouter Botzen WJ, Aerts JCJH (2017) Accounting for risk aversion, income distribution and social welfare in cost-benefit analysis for flood risk management. Wiley Interdiscip Rev Clim Change 8:e446. https://doi.org/10.1002/wcc.446
Knight FH (1921) Risk, uncertainty and profit. Houghton Mifflin, Boston
KNMI (2021) KNMI Klimaatsignaal'21: hoe het klimaat in Nederland snel verandert. De Bilt
Kwakkel JH (2020) Is real options analysis fit for purpose in supporting climate adaptation planning and decision-making? Wiley Interdiscip Rev Clim Change 11:e638. https://doi.org/10.1002/WCC.638
Kwakkel JH, Haasnoot M, Walker WE (2015) Developing dynamic adaptive policy pathways: a computer-assisted approach for developing adaptive strategies for a deeply uncertain world. Clim Change 132:373–386. https://doi.org/10.1007/s10584-014-1210-4
Lorek S, Fuchs D (2013) Strong sustainable consumption governance—precondition for a degrowth path? J Clean Prod 38:36–43. https://doi.org/10.1016/J.JCLEPRO.2011.08.008

Luthe T, Wyss R, Schuckert M (2012) Network governance and regional resilience to climate change: empirical evidence from mountain tourism communities in the Swiss Gotthard region. Reg Environ Change 12:839–854. https://doi.org/10.1007/s10113-012-0294-5

Malekpour S, Walker WE, De Haan FJ et al (2020) Bridging decision making under deep uncertainty (DMDU) and transition management (TM) to improve strategic planning for sustainable development. Environ Sci Policy 107:158–167. https://doi.org/10.1016/j.envsci.2020.03.002

Markowitz EM, Shariff AF (2012) Climate change and moral judgement. Nat Clim Change 2(4):243–247. https://doi.org/10.1038/NCLIMATE1378

Matin N, Forrester J, Ensor J (2018) What is equitable resilience? World Dev 109:197–205. https://doi.org/10.1016/j.worlddev.2018.04.020

McInerney D, Lempert R, Keller K (2012) What are robust strategies in the face of uncertain climate threshold responses? Clim Change 112(3):547–568. https://doi.org/10.1007/S10584-011-0377-1

Merkhofer MW (2012) Decision science and social risk management: a comparative evaluation of cost-benefit analysis, decision analysis, and other formal decision-aiding approaches. Springer Science & Business Media, Berlin

Miller D (2021) Justice. In: Stanford encyclopedia of philosophy. https://plato.stanford.edu/archives/fall2021/entries/justice/. Accessed 16 Dec 2021

Moss R, Scarlett PL, Kenney MA et al (2014) Ch. 26: Decision support: connecting science, risk perception, and decisions. Climate Change Impacts in the United States: The Third National Climate Assessment. Washington, DC

Newell P, Srivastava S, Naess LO et al (2020) Towards transformative climate justice: key challenges and future directions for research. Institute for Development Studies, Brighton. https://www.ids.ac.uk/publications/towards-transformative-climate-justice/

Pauwels N, Van De Walle B, Hardeman F, Soudan K (2000) The implications of irreversibility in emergency response decisions. Theory Decis 49:25–51. https://doi.org/10.1023/A:1005155426945

Peters O (2019) The ergodicity problem in economics. Nat Phys 15:1216–1221. https://doi.org/10.1038/s41567-019-0732-0

Peters O, Gell-Mann M (2016) Evaluating gambles using dynamics. Chaos Interdiscip J Nonlinear Sci 26:023103. https://doi.org/10.1063/1.4940236

Rawls J (1958) Justice as fairness. Philos Rev 67:164–194

Rawls J (1999) A Theory of Justice, Revised edn. Harvard University Press. https://doi.org/10.2307/j.ctvkjb25m

Roemer JE (2011) The ethics of intertemporal distribution in a warming planet. Environ Resour Econ 48:363–390. https://doi.org/10.1007/s10640-010-9414-1

Rosenhead J (1980) Planning under uncertainty: II. A methodology for robustness analysis. J Oper Res Soc 31:331–341. https://doi.org/10.1057/jors.1980.60

Sanklecha P (2017) Should there be future people? A fundamental question for climate change and intergenerational justice. Wiley Interdiscip Rev Clim Change 8:453. https://doi.org/10.1002/wcc.453

Schuppert F (2011) Climate change mitigation and intergenerational justice. Env Polit 20:303–321. https://doi.org/10.1080/09644016.2011.573351

Sen A (2017) Collective choice and social welfare. Harvard University Press, Cambridge

Sunstein CR (2010) Irreversibility. Law Probab Risk 9:227–245. https://doi.org/10.1093/LPR/MGQ010

Taebi B, Kwakkel JH, Kermisch C (2020) Governing climate risks in the face of normative uncertainties. Wiley Interdiscip Rev Clim Change 11:e666. https://doi.org/10.1002/WCC.666

Thiery BW, Lange S, Rogelj J et al (2021) Intergenerational inequities in exposure to climate extremes. Science (80-). https://doi.org/10.1126/SCIENCE.ABI7339

Tremmel JC (2006) Handbook of intergenerational justice. Edward Elgar Publishing, Cheltenham

Underdal A (2010) Complexity and challenges of long-term environmental governance. Glob Environ Change 20:386–393. https://doi.org/10.1016/j.gloenvcha.2010.02.005

Urban MC (2015) Accelerating extinction risk from climate change. Science (80-) 348:571–573. https://doi.org/10.1126/SCIENCE.AAA4984/SUPPL_FILE/URBAN-SM.PDF

Van der Hijden K, Olsen S, Scott A (2014) From solidarity to universality—how global interdependence impacts the post-2015 development agenda. IRF Backgr Pap

De Lotto R, Di Popolo V, Venco E (2016) From resilience to flexibility: urban scenario to reduce hazard. Int J Sustain Dev Plann 12(4):789–799. https://doi.org/10.2495/SDP-V12-N4-789-799

Walker W, Haasnoot M, Kwakkel J (2013) Adapt or perish: a review of planning approaches for adaptation under deep uncertainty. Sustainability 5:955–979. https://doi.org/10.3390/su5030955

Weiss EB (1992) In fairness to future generations and sustainable development. Am Univ J Int Law Policy 8:19

Yzer JR, Walker WE, Marchau VAWJ, Kwakkel JH (2014) Dynamic adaptive policies: a way to improve the cost—benefit performance of megaprojects? Environ Plann B: Urban Anal City Sci 41:594–612. https://doi.org/10.1068/B39088