Climate tipping points and intergenerational justice

The implications of climate tipping points and resilience theory for the sustainability component of intergenerational justice

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Abstract

This thesis discusses the implications of climate tipping points for intergenerational justice and for the sustainability component of intergenerational justice. Climate tipping points further amplify initial anthropogenic warming by starting irreversible natural feedback loops. The demands of intergenerational justice are contested. I argue that a baseline requirement is that future generations are granted the opportunity to meet their basic needs. This implies that climate tipping points should not be crossed. Sustainability, a necessary condition for intergenerational justice, requires system resilience. This implies that fostering the stability of the systems on which mankind depends should be a priority for intergenerational justice.

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Glossary of terms

Holocene	The relatively temperate geological period of the past 10,000 years (Crutzen, 2002).
Anthropocene	The new geological period where mankind is a geological force and influences the way the Earth System behaves (Crutzen, 2002).
Complex Adaptive Systems	Complex adaptive systems are self-organising: they exist in a certain regime, and tend to persist in this regime unless disturbances push it into another regime (Levin, 1998).
Resilience	"The capacity of a system to absorb disturbance and re-organize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks" (Folke, 2006, p. 259).
Panarchy	A set of nested complex adaptive systems. Higher level systems influence lower level systems, and vice versa (Gunderson & Holling, 2002).
Tipping element	A system (or element) that is vulnerable to tipping into a new regime (Lenton et al., 2008).
Tipping point	The point at which a tipping element moves into a new regime (Lenton et al., 2008).
Feedback loop	The secondary effect of a change. In a positive feedback loop, an initial change is enhanced by its secondary effect; in a negative feedback loop, an initial change is dampened by its secondary effect (Walker & Salt, 2006).
Intergenerational Justice	Justice between generations, e.g. between current and future generations. Typically conceptualised as a distributive matter (Meyer, 2016).
Intragenerational Justice	Justice within a generation, e.g. between the current developed world and the current developing world (Meyer, 2016).
Earth System Stewardship	Earth System Stewardship holds that humanity should take an active role in trying to ensure that the Earth System is in a resilient regime that is conducive to meeting basic human needs (Chapin et al., 2011; Folke et al., 2016; Steffen et al., 2018).

1. Introduction

In this thesis, I will discuss the implications of climate tipping points and resilience theory for intergenerational justice, specifically for the sustainability component of intergenerational justice. To fully understand what this means, more background is needed. First of all, humanity has grown so much in both number and influence over the past centuries, that it has now become a geological force (Crutzen, 2002; Steffen et al., 2015a). One of the most salient issues of the Anthropocene is that of climate change (but this is not the only issue – see Rockström et al., 2009; Steffen et al., 2015b). Due to human activities such as burning fossil fuels, the concentration of greenhouse gasses in the atmosphere increases. These gasses cause the Earth to retain solar heat more effectively, which can have potentially devastating consequences. Of particular concern is the existence of 'tipping points' – thresholds which, when crossed, start natural feedback loops in the Earth System that further amplify warming (Lenton et al., 2008). For example: white Arctic sea ice reflects sunlight. As this melts away, it exposes black ocean water which absorbs heat. This starts a vicious cycle which amplifies warming. Once started, these feedback loops are all but impossible to stop. The presence of these tipping elements in the Earth System has led some scientists to suggest that there could be a 'planetary tipping point' related to climate change, at which the warming caused by natural feedback loops could cause the crossing of other tipping points, thus like tipping cascades amplifying warming to dangerous levels (Steffen et al., 2018).

These climate tipping points may have major implications for intergenerational justice. Intergenerational justice concerns what is owed to future generations. It is often seen as a distributive matter – how much of a certain good (often defined as utility or welfare) should we bestow on future people? I aim to show that even a very weak account of intergenerational justice that is based on widely held assumptions will lead to the conclusion that we should not cross climate tipping points. It is argued that every generation should have the opportunity to meet their basic needs – this is taken to be the baseline requirement that virtually any theory of intergenerational justice would need to fulfil. There are massive costs associated with crossing climate tipping points, and if the present generation fails to prevent crossing these tipping points, the consequences will be felt by generations to come for centuries, if not millennia. If climate tipping points are crossed, the opportunity for future generations to meet their basic needs is diminished (IPCC, 2018; USGCRP, 2018; WMO, 2019). Therefore, intergenerational justice requires that we do not cross tipping points.

One finding of this thesis is that intergenerational justice requires that we do not cross climate tipping points. It turns out that this is an iteration of an underlying logic. Sustainability is a necessary condition for intergenerational justice: the requirements of intergenerational justice must be met indefinitely. Resilience theory, which also taught us about tipping points, teaches that systems can only persist if they can cope with disturbances while maintaining essentially the same form (Williams et al., 2017). System resilience, which is the capacity of a system to absorb disturbances and change while retaining the same form or identity, is thus a necessary condition for sustainability. Since sustainability is a necessary condition for intergenerational justice, system resilience is also a necessary condition for intergenerational justice. Mankind may be able to actively foster the resilience of the systems on which we depend, which is called Earth System Stewardship.

This introductory chapter will provide more details on climate change, resilience theory, and tipping points in Section 1.1; on intergenerational justice and sustainability in Section 1.2; and on the scope, structure, and research question of this thesis in Section 1.3.

1.1 Climate change, resilience theory, and tipping points.

This section will provide a brief overview of climate change, resilience theory, and tipping points. A more exhaustive discussion is provided in Chapter 2. Conditions of the Holocene – the relatively temperate period of the last 10,000 years which saw humanity thrive – are changing rapidly. Now, human actions have pushed the Earth System to a new geological epoch: the Anthropocene. Mankind has become so impactful that it has become a geological force. There is some debate about when exactly the Anthropocene began. Crutzen (2002), who coined the term, suggests that this Age of Man began with the Industrial Revolution – when John Watson invented the steam engine in 1784. Steffen et al. (2015a), however, suggest that we left the Holocene in the year 1950. This is when several Earth System indicators experienced an uptick (e.g. human population; land use; ocean acidification; stratospheric ozone) a trend which the authors call the Great Acceleration. They conclude that "only beyond the mid-20th century is there clear evidence for fundamental shifts in the state and functioning of the Earth System that are beyond the range of variability of the Holocene and driven by human activities" (Steffen et al., 2015a, p. 81).

Mankind's impact on Earth is enormous, and is harmful in many ways (Rockström et al., 2009; Steffen et al., 2015b). Climate change may be the greatest challenge of all. Due to human activities such as burning fossil fuels (which increases the amount of greenhouse gasses in the atmosphere) and deforestation (which reduces the Earth's ability to sequester greenhouse gasses), the concentration of greenhouse gasses such as CO_2 in the atmosphere has skyrocketed (Scripps, 2019). These gasses cause the Earth to retain solar heat more effectively, and hence warm the planet. This warming is dangerous in many ways: it can cause sea level rise, desertification, and it can increase the frequency and severity of extreme weather events such as hurricanes or droughts (AAAS, 2009; IPCC, 2014; 2018; USGCRP, 2018). These consequences are often delayed, which makes climate change an archetypical intergenerational justice issue.

In discussions about climate change, there is often an implicit assumption that there exists a linear relation between emissions and temperature increase. However, although this assumption is intuitively appealing, it is false. The Earth is a complex adaptive system. Such systems typically exist in a relatively stable regime where it is capable of absorbing disturbances while maintaining the same essential form and structure. This stability persists until a threshold is breached. Then, the system suddenly collapses and finds itself heading towards a different stable regime. The likelihood of breaching such a threshold increases as the system becomes less resilient (Holling, 1973). Resilience can be introduced with an example. Imagine a lake. It exists in a relatively stable state: there are some species of fish and plants thriving in the lake. As some external factors change – for example, some agricultural fertilizer waste finds its way into the lake – the system can initially absorb this disturbance and maintain the same form. It will still house some fish and some plants. However, as the runoff from agriculture reaches a tipping point, the increase in fertilizer nutrients that this runoff brings can cause an algal bloom (i.e. an explosion in the growth of algae). These algae then deplete oxygen levels in the water, effectively drowning the fish, and block sunlight, which kills the plant life. When the algae eventually die, the lake is depleted of oxygen, and unsupportive to life. This is a stable state again: it is almost impossible to move the lake back to the state with fish and plants (Walker & Salt, 2006; 2012).

Resilience theory can be understood with a ball-in-basin metaphor (Figure 1). The ball represents a system. The ball moves around the valley due to disturbances. As long as the ball remains in the valley, the ball has a tendency to roll down into the same valley. This valley is also called a basin of attraction. External changes can reduce the depth of the valley, making it easier for the ball to roll into a different valley. The shallower the valley, the less resilient the system is. Once the ball is in a new valley it is difficult, if not impossible, to roll it back up the hill into the former valley (Walker & Salt, 2006).

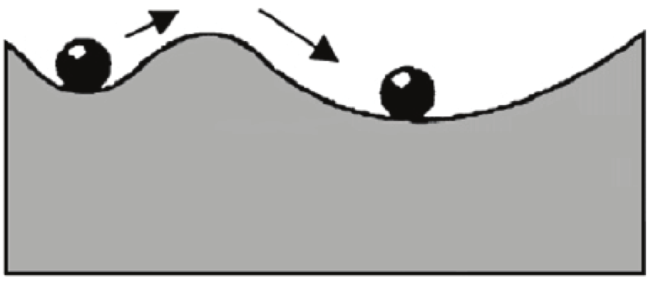

Figure 1. Ball and basin heuristic of system stability. The ball represents a system, the valleys represent stability domains, and the arrows represent disturbances. Adapted from Gunderson (2000, p. 427).

Climate change affects the resilience of several sub-systems of the Earth System. These sub-systems are strongly interconnected (more on that in Chapter 3). Recent science has found that climate change has reduced the resilience of several systems and that these systems are now at risk of tipping into a new regime. As these systems change regimes, they can further amplify warming (Lenton et al., 2008). In Chapter 3, a more detailed description of three tipping elements in the Earth System is given: the disappearance of Arctic sea ice, the transformation of the Amazon rainforest into a savannah ecosystem, and the thawing of permafrost. Here, I'll briefly discuss the last example, the thawing of permafrost, to illustrate the logic.

Some ground in the Arctic Circle is permanently frozen. Captured in this permafrost is ancient vegetation. As the Earth warms due to human activities, some of this permafrost will melt. As it melts, the biomass will rot and thereby release greenhouse gasses such as carbon dioxide and methane into the atmosphere (Schuur et al., 2015). These gasses contribute to further climate change and warming, and therefore more permafrost melts, which again releases more greenhouse gasses. In this way, a self-enforcing feedback loop is started which will further amplify initial anthropogenic climate change (Lenton et al., 2008).

This feedback loop with thawing permafrost is just one of several systems that are currently under pressure. All of these systems can interact. As, for example the disappearance of Arctic sea ice amplifies warming, this additional warming can start other feedback loops, such as the permafrost feedback loop. The warming caused by thawing permafrost could again start other feedback loops, and so on. Steffen et al. (2018) suggest that there might be a planetary tipping point, at which several local ecosystems collapse and this disturbance causes other systems to collapse.

These tipping points are particularly relevant for the discussion on intergenerational justice and climate change. Actions of the present generation can push the Earth past a tipping point, and once that point is crossed, irreversible changes are set in motion. The expected changes (e.g. sea level rise, failing harvests, desertification) would be harmful to future generations. The next section will discuss what this means for intergenerational justice.

1.2 Intergenerational justice and sustainability

This section will provide a concise outline of intergenerational justice and sustainability. First, the argument is made that intergenerational justice requires that climate tipping points are not crossed. Although there is significant debate in the field, most theories of intergenerational justice accept the baseline that future generations should have the opportunity to meet their basic needs. If we accept this, and accept that the crossing of climate tipping points diminishes the ability of future generations to meet their basic needs, it follows that intergenerational justice requires that climate tipping points are not crossed. Second, the case is made that sustainability is a necessary condition for intergenerational justice. Sustainability, which fundamentally is nothing more than ensuring that certain outcomes are provided indefinitely, requires system resilience. In order to reliably provide the desired outcomes, the system must be able to weather inevitable disturbances and changes while maintaining the same form or identity. This implies that the resilience of the overall system that allows humans to meet their basic needs is a necessary condition for intergenerational justice. Mankind should seek to foster the resilience of the systems on which it depends, which is known as Earth System Stewardship. Furthermore, since the crossing of tipping points can be irreversible and the consequences of doing so are harmful, I argue that Earth System Stewardship should have priority. Both arguments are discussed more in-depth in Chapter 3.

Climate tipping points and intergenerational justice

Intergenerational justice concerns what is owed to future generations. It is typically seen as a distributive matter – how much of a certain good (e.g. utility) should we bestow on future people? There are many different theories of intergenerational justice, and a more general review is provided in Chapter 3. The aim of this thesis is not to further complicate the debate by adding to this already diverse discipline, but rather to show that an uncontroversial, baseline theory that is based on widely held assumptions can lead to significant conclusions. Therefore, this paragraph will set out what such a general, uncontroversial theory of intergenerational justice would look like, and will detail the premises on which it is built. I find that intergenerational justice requires that future generations have the opportunity to meet their basic needs. Since crossing climate tipping points diminishes the ability of future generations to meet their basic needs, intergenerational justice requires that climate tipping points are not crossed.

First of all, the case is made that different persons have equal moral value, regardless of when they live. Time is thus a morally irrelevant factor (Barry, 1999; see Chapter 3 of this thesis). Some theories also ascribe value to animals or inanimate nature (e.g. Cochrane, 2006; Singer, 1974), but since the aim of this thesis is to provide a baseline theory of intergenerational justice, only human interests are considered. Accepting the premise that time is morally irrelevant opens the door for intergenerational justice: if time is morally irrelevant, future generations may have justice-based claims on the present generation. Now, however, the question remains *what* intergenerational justice should distribute (e.g. utility, welfare, or capabilities), and *how much* of that variable future generations have a right to.

There is much debate about *what* exactly it is that intergenerational justice should distribute among generations. For example, classic utilitarians will argue that it should be some notion of utility (Mill, 1863), while others such as Sen, Nussbaum, and Robeyns (2017) would argue that the variable should defined in terms of capabilities. Furthermore, there is debate about *how much* of this to-be-defined variable we owe to future generations. Barry (1999) and Wolf (2005) suggest that intergenerational justice requires that we leave the Earth in the same condition as we inherited it, or in a better condition. However, other theorists argue for a much less stringent requirement. For example, Meyer (2016) suggests that merely meeting the basic needs of future generations (the 'sufficiency threshold') is enough. These arguments will be discussed in more detail in Chapter 3, but I argue that it is not necessary to solve these contentious debates. I argue that any theory of intergenerational justice would find it necessary that future generations have the opportunity to meet their basic needs. In saying this, I build on Brian Barry's seminal article "Sustainability and Intergenerational Justice," and on Lukas Meyer's work on sufficientarianism. Barry argues that intergenerational justice requires that we "provide future generations with the opportunity to live good lives according to their conception of what constitutes a good life" (Barry, 1999, p. 104). This is somewhat vague, but this vagueness is in fact a strength. It does not yet fill in what future people may want, and thereby avoids the discussion of what variable intergenerational justice should be concerned with (e.g. utility, welfare, capabilities). The next step is inspired by Meyer (2016), who argues for sufficientarianism in intergenerational justice. In a nutshell, sufficientarianism contends that every individual should live on or above a certain minimal threshold – the sufficiency threshold. This is less stringent than Barry's account: whereas Barry talks about 'a good life,' sufficientarianism only requires that the bare minimum needs are met. Since the purpose of this thesis is to formulate a minimally controversial 'baseline' of intergenerational justice, a variant on Barry's formulation is proposed. Inspired by Brundtland (1987) as well as Meyer (2016), the requirement of intergenerational justice is defined as *providing future generations with the opportunity to meet their basic needs*. These basic needs would at least include the provision of clean drinking water, food, and housing. This is an improvement on Barry's formulation in that it is more specific – identifying the opportunity to meet basic needs as the relevant unit of comparison. The opportunity to meet basic needs is a prerequisite in order to achieve anything that would qualify as Barry's 'good life,' and is less ambiguous.

It is absolutely possible to disagree with this baseline: I imagine that many would think that it does not go far enough. It would be difficult, however, to argue that it is too stringent. This is because the opportunity of future generations to meet their basic needs is a necessary condition for other theories of intergenerational justice. For example, the fulfilment of the utility-based demands of intergenerational justice requires that the opportunity to achieve this utility is given. Anyone who argues for an account of intergenerational justice invoking notions of utility needs to provide future generations with the opportunity to meet their basic needs – this opportunity is a necessary condition to provide the utility. However, utility goes beyond opportunity, and already defines what exactly future generations should want (in this case, maximum utility). One of the aims of this thesis is to identify a baseline theory of intergenerational justice. Providing future generations with the opportunity to meet their basic needs is that baseline.

Thus far, we have found that intergenerational justice requires that future generations have the opportunity to meet their basic needs. Based on the discussion in Section 1.1, it seems likely that the crossing of climate tipping points would reduce the ability of future generations to meet their basic needs. For example, as climate change is expected to increase the frequency and severity of extreme weather events, harvests are likely to fail more often and could thereby damage food security (USGCRP, 2018). Altered precipitation patterns could result in droughts – putting the supply of clean drinking water at risk (IPCC, 2014; 2018). With sea level rise, several coastal regions will eventually become uninhabitable, which could create millions of refugees (Steffen, 2011). Continued increases in surface temperatures could make parts of the Persian Gulf uninhabitable (Pal & Eltahir, 2016). This shows that the crossing of climate tipping points would diminish future generation's ability to meet their basic needs of food, access to clean drinking water, and housing. Furthermore, climate tipping points are irreversible and feedback loops ensure that warming continues even after emissions are stopped (Lenton et al., 2008; Steffen et al., 2018), which would further exacerbate all of these negative consequences.

What follows is a syllogism: combining the premise that intergenerational justice requires that future generations have the opportunity to meet their basic needs with the premise that the crossing of climate tipping points would diminish the ability of future generations to meet their basic needs leads to the conclusion that intergenerational justice requires that we do not cross climate tipping points.

Sustainability and intergenerational justice

The conclusion that intergenerational justice requires that we do not cross climate tipping points is an iteration of an underlying logic. That underlying logic starts with sustainability. Barry (1999) argues that sustainability is a necessary condition for intergenerational justice. Since there is no real reason to expect a stop in the accretion of new generations, we should ensure that the needs of future generations can be met indefinitely. The way the term sustainability is understood is typically that there is some outcome X (e.g. utility) which intergenerational justice requires to be provided ad infinitum. The stock of this X should never run out: the return of this variable must be optimized in such a way that all future generations can enjoy it (Barry, 1999; Wolf, 2005). Appealing as this understanding may be, it is mistaken. Resilience theory teaches that focussing on one variable or outcome is counterproductive, and results in reduced system resilience. "Success in controlling a narrow set of parameters may lead to surprising, and often adverse, outcomes in the broader system" (Folke et al., 2016, p. 41). Rather, resilience theory teaches that the ability of a system to adapt to disturbances while retaining essentially the same identity is necessary to sustainably provide certain outcomes. Resilience is more concerned with process, while sustainability is more concerned with outcomes (Redman, 2014). In order to ensure that the outcomes that intergenerational justice requires can be provided sustainably, the overall system must be resilient. System resilience is a necessary condition for sustainability.

This has several implications for intergenerational justice. If we accept that sustainability is a necessary condition for intergenerational justice, and we accept that system resilience is a necessary condition for sustainability, then system resilience becomes a necessary condition for intergenerational justice. This implies that keeping the Earth System in a resilient regime (i.e. a stable state, capable of absorbing disturbances while persisting in the same form) that is conducive to humans meeting their basic needs is a requirement of intergenerational justice. Given the earlier discussion of climate tipping points, this provides further support to the claim that intergenerational justice requires that we do not cross climate tipping points. Moreover, it suggests that the resilience of the overall system has priority, and that mankind should try to foster the resilience of the ecosystems on which it depends.

The area of research known as Earth System Stewardship holds that mankind should actively try to maintain the Earth System in a regime that it conducive to human welfare (Chapin et al., 2011; Folke et al., 2016; Steffen et al., 2018). Put in terms of intergenerational justice, Earth System Stewardship entails that mankind should make sure that the Earth remains in a regime that allows future generations the opportunity to meet their basic needs. In the Anthropocene, mankind is already a geological force, and effectively determines the trajectory of the Earth System. Actively trying to foster resilience of the systems on which mankind depends is better than to feign ignorance and continue as usual, which will likely lead to a future that is much less supportive of humanity meeting its basic needs. Given that system change can be irreversible, and given that the stakes are so high, I argue that priority should be given to fostering the resilience of the Earth System. Since the status quo is unsustainable, this implies that rapid and widespread change is needed (Steffen et al., 2018).

1.3 Scope, research question and structure

The crossing of climate tipping points can result in Earth becoming a place that is much less hospitable to human life. This, in turn, has the potential to challenge conventional accounts of intergenerational justice. Particularly the sustainability aspect of intergenerational justice may be subject to revision given climate tipping points and resilience theory. All of these aspects will be discussed in this thesis. To succinctly summarise the aim of this thesis, a research question has been formulated. This research question is as follows:

"What are the implications of climate tipping points and resilience theory for intergenerational justice, and for the sustainability component of intergenerational justice?"

This thesis is divided into four chapters. This first, introductory chapter has provided an overview of the aim of this thesis and has provided a general outline of the argument that will be followed. In Chapter 2, a more detailed background of climate change and human responses to it is given. The concentration of greenhouse gasses such as CO_2 has skyrocketed, and efforts to mitigate climate change have been inadequate. Resilience theory is introduced as well, as are climate tipping points. Systems typically exist in a relatively stable regime until they are pushed beyond their adaptive capacity. Then, the system can suddenly collapse and find itself in a new regime. Three examples of climate tipping points are provided. Lastly, the possibility of a planetary tipping point is discussed, where multiple small-scale tipping points push the Earth to a different regime.

Chapter 3 is divided into two sections. The first section of Chapter 3 introduces the debate on intergenerational justice, and provides the foundations for a baseline, minimal theory of intergenerational justice. The requirement of such a baseline theory is defined as granting future generations the opportunity to meet their basic needs. Next, a brief overview is given of the literature on climate change and intergenerational justice. To the best of my knowledge, there is no philosophical literature that combines climate tipping points with intergenerational justice. The earlier defined baseline theory of intergenerational justice is combined with the reality of climate tipping points, which leads to the conclusion that intergenerational justice requires that climate tipping points are not crossed (Figure 2).

Premise 1: Intergenerational justice requires that every generation has the opportunity to meet their basic needs.
Premise 2: If climate tipping points are crossed, future generation's ability to meet their basic needs is diminished.
Conclusion: Intergenerational justice requires that we do not cross tipping points.

Figure 2. Intergenerational justice requires that we do not cross tipping points.

In the second section of Chapter 3, the sustainability component of intergenerational justice is discussed. At its most abstract, sustainability means nothing more than ensuring that certain outcomes are achieved indefinitely. The defining characteristic of intergenerational justice is concern for the long-term provision of certain outcomes, and therefore sustainability is a necessary condition for intergenerational justice. In the literature on intergenerational justice, sustainability is often understood to concern the optimisation of the return of one or a limited set of variables. However, resilience theory teaches that focussing on one variable at the expense of others leads to reduced resilience. Rather, sustainability requires that the system can absorb disturbance while maintaining the same identity. This understanding of sustainability implies that the resilience of the Earth System in a regime that is conducive to the opportunity to meet human basic needs is a necessary condition for intergenerational justice. This, in turn, implies that mankind should seek to foster the resilience of the Earth in such a regime, which is known as Earth System Stewardship. Given the irreversibility of regime change, and the massive costs associated with crossing climate tipping points, I argue that Earth System Stewardship should be a priority of intergenerational justice.

The fourth and final chapter provides a conclusion. The main findings of this thesis are summarised, and the research question is answered. Climate tipping points provide a novel challenge to intergenerational justice. A baseline theory of intergenerational justice was formulated, which posits that future generations should be granted the opportunity to meet their basic needs. This baseline theory requires that climate tipping points are not crossed – a conclusion that will also hold for more stringent theories. Furthermore, it is found that system resilience is a necessary condition for sustainability and intergenerational justice. The stability of the overall Earth System is essential to achieve intergenerational justice, and with Earth System Stewardship mankind can actively try to make sure that the Earth remains in a regime that enables us to provide future generations with the opportunity to meet their basic needs.

2. Climate change, resilience theory, and tipping points

To understand the challenge that climate tipping points pose to intergenerational justice, it is first necessary to understand the background of climate change. Due to human activities, Earth has been warming. This chapter will first provide an overview of the science and consequences of climate change in Section 2.1. After establishing a basic understanding of the issue, resilience theory is introduced in Section 2.2. Complex adaptive systems tend to be stable and capable of dealing with disturbance while maintaining the same essential function. However, if this resilience is eroded, the system can suddenly change to a different regime. In Section 2.3, several climate tipping points are introduced. These systems are at risk of changing regimes – and these new regimes will likely further amplify climate change. If these systems change, they will lock in dangerous levels of warming. These dangerous levels of warming will, in turn, negatively affect the ability of future generations to meet their need. This is what makes it relevant for intergenerational justice. In the fourth and final section, the possibility of a planetary tipping point is discussed.

2.1 An overview of climate change

Before diving into the system complexities associated with climate change, it is useful to take a step back and summarize the basic logic behind climate change. In this section, I will argue that there is an increased concentration of CO_2 in the atmosphere; that the Earth has warmed because of this; and that human activity (primarily through burning fossil fuels) is responsible for this increase. After that, I'll briefly discuss the consequences of climate change and the human responses to it.

Scientists can determine what the atmospheric composition has been in the past by analysing air bubbles trapped in ancient ice. Such ice-core analysis shows that for more than 800,000 years, the concentration of CO_2 in the air has not transgressed the boundary of 300 parts per million (ppm) (NASA, 2018). Contemporary measurements, however, show that the concentration of CO_2 has been increasing: from about 315 ppm when measurements began in 1958 to more than 411 ppm in May 2018. This trend is now known as the Keeling curve (Scripps, 2019; Figure 3). Both the atmospheric CO_2 concentrations achieved and the rate of increase observed since 1958 are unprecedented. This is concerning because CO_2 is a greenhouse gas: it traps heat, and therefore an increase in CO_2 warms the Earth.

Observations corroborate the theory that CO_2 emissions have warmed the planet. First of all, it is getting warmer. Eighteen of the nineteen warmest years on record have occurred since the turn of the millennium – the odd one out was 1998. Nine of the ten warmest years on record have happened since 2005 (NOAA, 2019; WMO, 2019). This could be seen as (repeated) anecdotal evidence, but more robust scientific analyses further substantiate the anomalous nature of these temperature increase. A seminal study by Mann, Bradley and Hughes (1999) visualised the temperature increase in the millennium from 1000 to 2000 CE. This is now commonly known as the 'hockey stick curve' – the long period up to about 1900 was relatively flat, like the long shaft of a hockey stick. In the 20th century, however, the graph suddenly lurches upward, like the blade of a hockey stick, indicating a sudden increase in temperature (see Figure 9 in the appendix). These results have been repeated and corroborated by later research (Ahmed et al., 2013; Marcott et al., 2013). Furthermore, the type of warming observed fits with CO_2-caused warming. Roughly speaking, the temperatures in the lower 15km of the atmosphere have increased, while higher altitudes have gotten colder (Schwarzkopf & Ramaswamy, 2008; see Figure 10 in the appendix). CO_2 is a relatively heavy gas, and stays closer to the Earth's surface than other, lighter gasses. The observation that the lower atmosphere has become hotter while the upper atmosphere has become colder fits the theory that CO_2 causes warming, because CO_2 functions as a 'blanket' containing solar heat close to the Earth's surface.

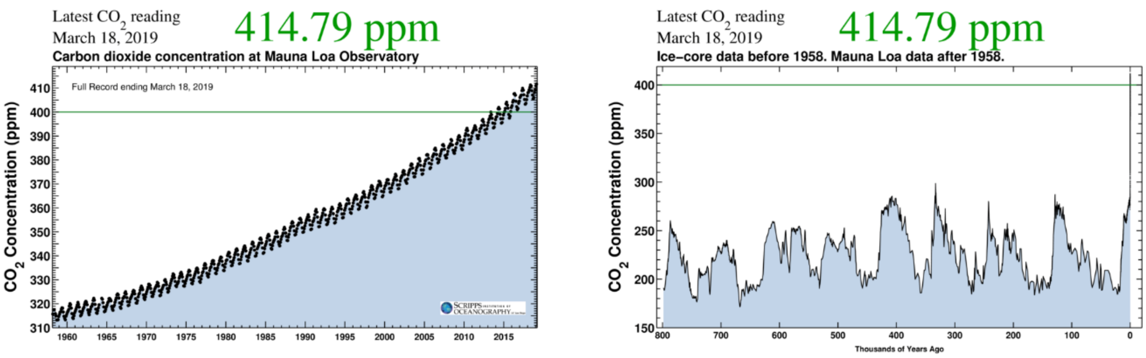

Figure 3. CO_2 measurements at the Mauna Loa observatory, 1958-present and complemented with ice-core data. The left graphic shows the measurements since 1958. This is known as the Keeling curve after Charles David Keeling, who initiated the measurements. The right graphic shows the anomalous nature of the recent increase when compared with ice-core data of the previous 800.000 years (Scripps, 2019).

This increase is due to human activity, primarily the burning of fossil fuels. First of all, this is common sense: we know that the burning of materials such as coal, oil, and gas emits CO_2, and we know that humanity has burned significant amounts of fossil fuels since the industrial revolution. But there is further evidence to suggest that humanity is behind this increase. The chemical element carbon exists in multiple different versions with varying neutron numbers. These different versions are called isotopes. Of these different isotopes, ^{12}C and ^{13}C are the most common in the atmosphere. Plants prefer ^{12}C to ^{13}C for photosynthesis. This means that plants tend to have a higher concentration of ^{12}C than the atmosphere in which it has grown. Fossil fuels are essentially ancient plants – organic materials turned into oil or coal by geochemical processes. Observations show that, in line with an increase in the burning of fossil fuels, concentrations of ^{12}C relative to ^{13}C have increased in both the atmosphere and in the ocean (Ghosh & Brand, 2003).

This provides further evidence that human activity – including the burning of plant-based fossil fuels – is behind the increased concentration of CO_2 in the atmosphere and in the ocean.

Consequences

Forecasts about what might happen due to climate change are difficult to make. While the extent of the consequences is hard to predict, the underlying mechanisms are better understood. For example, tropical storms (also known as hurricanes, typhoons, or cyclones, depending the region in which the storm occurs) form over warm water. As climate change causes water to warm, the frequency and severity of tropical storms has increased (Webster et al., 2005) and is likely to increase further in the future (Knutson et al., 2010).

The sea level rise that the Earth has experienced thus far has primarily been due to thermal expansion of the oceans. With the melting of ice caps and glaciers, a 2°C increase is expected to eventually lead to a sea level rise of 25 meters, but this is a slow process: "it would take many more centuries or even a millennium or two for the full sea-level rise to be realized" (Steffen, 2011, p. 23). Because of the inertia inherent to the Earth System, there is often a delay between the crossing of a threshold and the moment when the consequences are felt.

Other consequences of climate change include the loss of biodiversity, desertification, and ocean acidification. Extreme weather events such as heatwaves, droughts, floods, and aforementioned tropical storms will likely become more frequent and more severe (IPCC, 2014; IPCC, 2018). A recent report by the government of the United States found that bushfires in that country should be less frequent than they are nowadays by 2090 – but only because most of the forests susceptible to them will have already been burned to a crisp by then (USGCRP, 2018). The same report also found that climate change could reduce the GDP of the United States by 10% by the end of the century. Climate change will affect humans in many ways, virtually all of which are harmful. A recent study found that limiting the temperature increase to 1.5°C above pre-industrial levels by the end of the century would be significantly less harmful than allowing the temperature to increase by 2°C (IPCC, 2018). However, human action to mitigate climate change has been less than impressive, and both the 1.5°C scenario and the 2°C scenario seem very optimistic.

Human responses

Knowledge about climate change has been around for a while. In the late 19th century, Swedish geologist Svante Arrhenius continued the earlier work of Tyndall (1861) to conclude that atmospheric concentrations of greenhouse gasses such as CO_2 could influence 'the temperature on the ground' (Arrhenius, 1896). Political action has taken some time to follow scientific progress. Eventual action has primarily come from international negotiation, under the United Nations Framework Convention on Climate Change (UNFCCC), founded in 1992. Generally, climate action is divided in two priorities: mitigation and adaptation. Mitigation refers to "human intervention to reduce the sources or enhance the sinks of greenhouse gases" (IPCC, 2014, p. 37), or, in other words, acting now to make sure future climate change is less severe. Adaptation, on the other hand, refers to action taken to live with the consequences of climate change – for example, building cooler homes.

Two main accords have been reached under the UNFCCC: the Kyoto Protocol of 1997, and the Paris Agreement of 2015. The latter expresses the intention to limit warming to "well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (United Nations, 2015, p. 3). This is an ambitious target. Unfortunately, models[1] suggest that current policies are wildly insufficient to reach the targets set out in the Paris Agreement (Figure 4). This has led some scientists to express their scepticism about the feasibility of these targets: "there is virtually no chance that the rise in temperature will be less than the target 2°C even with immediate, universal, and ambitious climate change policies" (Nordhaus, 2018, p. 358).

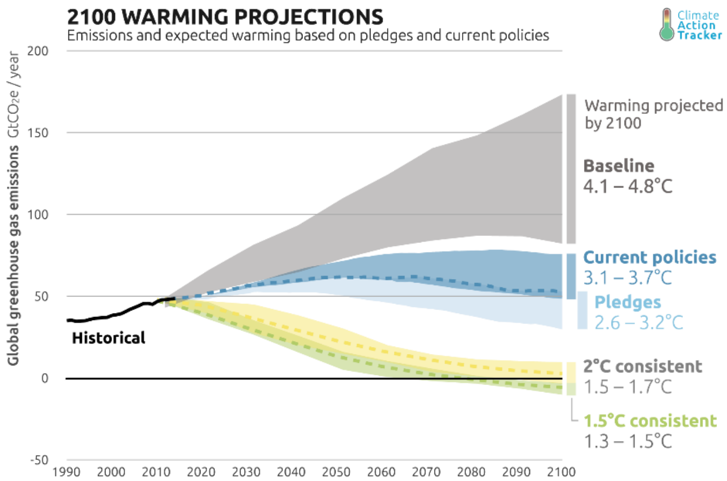

Figure 4. 2100 warming projections, current policies versus 2°C (Climate Action Tracker, 2019).

2.2 Resilience theory

The discussion of climate change, its consequences, and human action to mitigate it appears to implicitly assume a linear relation between greenhouse gas emissions and temperature. However, complex adaptive systems typically don't behave that way. Rather, such systems exist in a relatively stable regime, capable of withstanding disturbances and stresses while maintaining its same essential form and function, until a threshold is breached and the system suddenly collapses and finds itself in a new regime. This understanding of system behaviour is known as resilience theory (Holling, 1973; Folke, 2006; Walker & Salt, 2006). In this

[1] These models are troubled. One issue is that many scenarios presume that humanity will have net-negative emissions (taking more carbon out of the atmosphere that it is putting in) in the latter part of the 21st century. Of the 116 IPCC scenarios consistent with reaching the 2°C target, 101 presume negative emissions (Fuss et al., 2014). This is troublesome because there are no reliable negative emissions technologies yet (Peters, 2015) and the presumption that these will develop and scale without issue seems optimistic at best.

section, resilience theory will be explained. In doing so, the concept of tipping points is introduced as well. The next section will detail some tipping points related to climate change.

The roots of resilience lie, at least in part, in research into ecological systems. C.S. Holling (1973) was one of the first researchers to suggest that observed non-linear behaviour in ecosystems may be explained by resilience. Challenging the dominant notion that ecological change is to be understood as shifts to slightly different equilibria, Holling suggested that systems can resist a given amount of disturbance while maintaining the same function, before a threshold is crossed and the system starts behaving as a different system – a different regime. This idea may be best explained with an example. Imagine a forest. The flora and fauna in the forest behave independently, and change continuously. Trees grow and die, and the wildlife lives and dies. The behaviour of the overall ecosystem, however, is self-organising. The death of one tree does not entail the death of the forest: a healthy forest self-organizes and a new sapling will start to grow where the old tree has died. The overall forest maintains essentially the same structure and function – it is a complex adaptive system. A complex adaptive system has the potential to exists in multiple different regimes (also called alternative stable states), and does not change regimes in a linear or predictable fashion (Levin, 1998). For example, the area of land which is currently a forest, might have been a savannah or a desert. If the forest experiences enough disturbances, it may switch regimes and move from a forest-regime to a savannah-regime or a desert-regime.

In the first chapter, resilience was introduced with the heuristic of valleys (Figure 1; Gunderson, 2000). The system, represented by a ball, moves around the valley because of disturbances. As long as it remains in the valley, the ball has a natural tendency to roll back down into the valley. However, if the ball moves too far away, it could – so to speak – tip over the mountain ridge and roll into another valley. In the literature on resilience theory, this valley is called a basin of attraction. This basin of attraction represents a regime. Regimes are alternative stable states. For example, one basin of attraction of a local ecosystem may be forest; another may be a savannah or a desert. The ball in the basin of attraction can move around: the forest may experience a minor wildfire. As the system moves away from the basin of attraction, it eventually glides back down. However, if there is a disturbance so great that it pushes the system beyond the reach of the basin of attraction, it finds itself rolling into an entirely a new basin – a new regime. For example, after years of drought and wildfires, a forest may cease to exist and enter a new regime. It could, for example, transform into a savannah ecosystem. The depth of the basin, the width of the basin, and the location of the ball constitute the system's resilience: the deeper the basin, the more capable the system is of absorbing disturbances that nudge it around. A system in a shallow basin (a less resilient system) requires little disturbance to be pushed over the edge into another state (Walker & Salt; 2006; 2012; Figure 5).

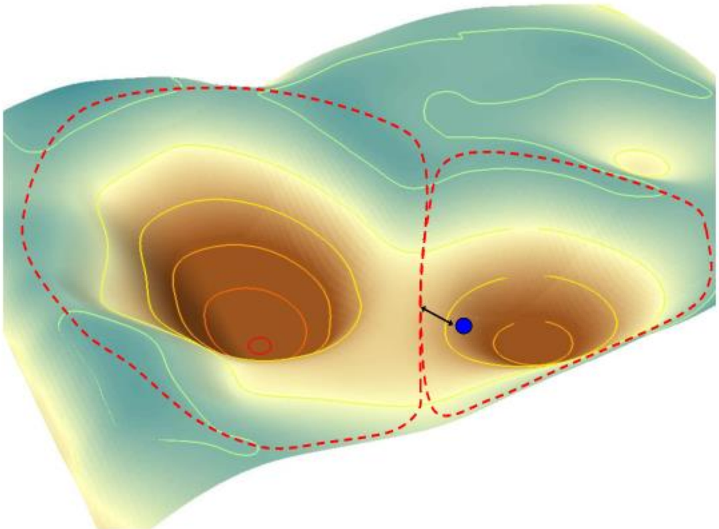

Figure 5. Visualised basin of attraction. The blue ball represents the system. It is moving around in one basin of attraction. If it crosses the tipping point (broken red line), it will be drawn to another basin of attraction and enter another regime. From Walker and Salt (2006, p. 54).

Complex adaptive systems are embedded in one another. For example, a coral reef can be understood as a complex adaptive system, but so can an individual coral or even an entire ocean. All of these exist on different hierarchical levels, but influence each other. This is what Holling (2001) called a panarchy: a set of nested complex adaptive systems. Higher levels, such as the ocean, influence lower levels, such as coral reefs, and vice versa. "Each level is allowed to operate at its own pace, protected from above by slower, larger levels but invigorated from below by faster, smaller cycles of innovation" (Holling, 2001, p. 390). Changes in one system (for example, a coral reef) have impact on another system (for example, an ocean) and vice versa. It is not possible to understand one system in isolation from the others (Gunderson & Holling, 2002).

Put simply, two factors influence resilience: the position of the ball and the shape of the basin. If the system changes and becomes less resilient, the basin of attraction becomes shallower and subsequently less of a disturbance is required to push the system over a threshold and into a new regime. "From a resilience perspective the question is how much change can occur in the basin and in the system's trajectory without the system leaving the basin" (Walker & Salt, 2006, p. 54). The fear with regards to climate change is that due to the increased concentration of greenhouse gasses in the atmosphere and the associated rise in temperature, systems may lose resilience and cross tipping points into a new regime (see Section 2.3). These new regimes are expected to be less conducive to (human) life than the current regimes. This can happen in local, smaller systems first, but will eventually affect greater systems. In other words, as lower level systems lose resilience and move to a different regime, the change reverberates up the panarchy and could reduce the resilience of higher level systems (Gunderson & Holling, 2002).

Of particular concern is that undesirable states can be very resilient. In other words, once a systems rolls into a new basin of attraction, it can be all but impossible to push it back out. “Once a tipping point has been crossed, there is no way for humanity to reverse the change, no matter how deleterious or even catastrophic the new behaviour of the climate system might be” (Steffen, 2011, p. 27). This irreversibility of regime change raises the stakes, and would warrant the use of a precautionary approach. With such high stakes, it is better to err on the side of caution. Scientists have already identified natural feedback loops that can further exacerbate initial anthropogenic warming. The following section will detail some of these tipping elements.

2.3 Climate tipping points and feedback loops

Some researchers fear that feedback loops in the Earth System have the potential to push the entire Earth System into a new regime – a regime that may be much less conducive to human life than the Holocene (Steffen et al., 2018). Once local systems are pushed beyond certain thresholds, self-amplifying feedback loops may be started that ensure further warming. Lenton et al. (2008) have identified some of these thresholds, which they call tipping points (Figure 6). In this section, three feedback loops with regards to climate change are discussed: the disappearance of Arctic summer sea ice; the transformation of the Amazon rainforest into a savanna ecosystem; and the thawing of permafrost.

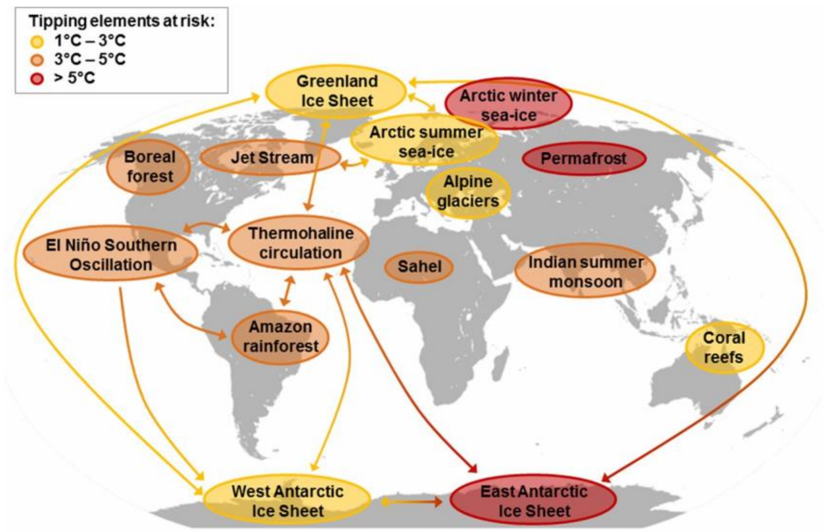

Figure 6. Climate tipping points in the Earth System. From Steffen et al. (2018, p. 8255).

The first example is the disappearance of Arctic summer sea ice. White sea ice has a high albedo (‘whiteness’); it reflects sunlight and heat, while black ocean water has a low albedo; it absorbs solar radiation and heat. As Arctic sea ice disappears due to initial warming caused by mankind, a feedback loop is started in which more black ocean water retains solar heat, which causes warming, which in turn causes more white sea ice to disappear, which causes more black ocean water to retain heat, and so on. Some researchers suggest that the tipping point to a summer without Arctic sea ice has already been crossed. Like with sea-level rise, system inertia ensures that the reaction is delayed, but Lindsay and Zhang (2005) and Serreze, Holland and Stroeve (2007) suggest that current levels of climate change ensure that the Arctic will be ice-free in summer within a few decades. The extent of summer sea ice has been declining, and the rate of decline is outpacing that of linear models (NSIDC, 2018). Therefore, "a summer ice-loss threshold, if not already passed, may be very close and a transition could occur well within this century" (Lenton et al., 2008, p. 1789).

Similar system dynamics exist throughout the world. For example, climate change is expected to alter rainfall patterns in the Amazon rainforest. Increasingly frequent droughts make the forest more susceptible to wildfires, which can eventually trigger a collapse of (parts of) the rainforest system and cause a sudden conversion to a grassland or savanna ecosystem (Foley et al., 2007; Brienen et al., 2015). If this were to happen, it would first of all emit significant amounts of CO_2: wildfires during the collapse of the system would send carbon that had been stored in vegetation into the atmosphere. Secondly, savannas absorb significantly less carbon than rainforests. Such a transformation of the Amazon system would seriously debilitate one of the largest carbon sinks on Earth, reducing the ability of the Earth to sequester atmospheric carbon, and thereby ensure further warming (Rockström et al., 2016).

A third notable feedback loop is the thawing of permafrost. Some ground in the Arctic Circle is permanently frozen – this is aptly called permafrost. Captured in this frozen ground is ancient biomass. This biomass (essentially rotting vegetation in ice) stores significant amounts of carbon dioxide (CO_2) and methane[2] (CH_4) (Schuur et al., 2015). As initial warming causes the latitude of permafrost to edge further northward, some permafrost thaws, releasing carbon and methane, which causes the Earth to warm up more. As Earth warms up more, more permafrost will thaw, further amplifying the greenhouse effect (Lenton et al., 2008). Recent research suggests that this thawing of permafrost may occur at a much faster rate than originally thought (Anthony et al., 2018). As permafrost thaws and it emits carbon and methane into the atmosphere, a depression forms. To put it simply – a hole forms in the ground. This hole is then filled with water from precipitation and melting snow. This water increases the thaw-rate at the edges of the newly formed lake. Over a timespan of decades, these 'abrupt thaw processes' can create holes tens of meters deep. In effect, the permafrost under these lakes is flash-thawed and the ancient greenhouse gasses stored in the permafrost find their way into the atmosphere. The authors reach

[2] Methane is a potent greenhouse gas: "On a molecule-for-molecule basis, it is more than 20 times as potent a greenhouse gas as carbon dioxide" (Badr, Probert, & O'Callaghan, 1991, p. 273).

the unsettling conclusion that "in contrast to shallow, gradual thaw that may rapidly re-form permafrost upon climate cooling, deep, CH_4-yielding abrupt thaw is irreversible this century. Once formed, lake taliks continue to deepen even under colder climates, mobilizing carbon that was sequestered from the atmosphere over tens of thousands of years" (Anthony et al., 2018, p. 7). The authors note that this abrupt thaw process is not included in current climate prediction models. According to Gasser and colleagues (2018), this implies that the mitigation path followed is relevant – permafrost thaw is path dependent. This means that if a climate change mitigation path is followed where emissions first go up, to then decrease sharply, the permafrost feedback loop may already be started and will not be stopped by later mitigation. Once the feedback loop is started, it cannot be stopped. This path dependency entails that immediate mitigation is to be preferred to 'peak and decline' scenarios (Gasser et al., 2018).

Once a tipping point is crossed, it is all but impossible to pull the system back into its original regime. The irreversibility of natural feedback loops such as those introduced above have significant implications for intergenerational justice. The negative consequences of warming for humanity include decreased food security due to desertification and more frequent and severe extreme weather events (IPCC, 2014; 2018), and some areas may become uninhabitable due to sea level rise (Steffen, 2011) or temperature increase (Pal & Eltahir, 2016). If climate tipping points are crossed, these consequences will be felt by future generations. Furthermore, these generations will be powerless to reverse the change that was started by crossing the tipping points. This makes climate tipping points an intergenerational justice issue. Chapter 3 will discuss the implications of climate tipping points for intergenerational justice.

2.4 Tipping cascades

Steffen and colleagues suggest that, once started, these various tipping elements may amplify one another, and like tipping cascades push the Earth System on a trajectory towards a 'hothouse Earth' regime – a place that is "uncontrollable and dangerous to many […] and it poses severe risks for health, economies, political stability (especially for the most climate vulnerable), and ultimately, the habitability of the planet for humans" (Steffen et al., 2018, p. 8256). The initial tipping points crossed will result in some additional warming, which may in turn cause other feedback loops to start, resulting in even more warming. Steffen et al. (2018) suggest that the 'planetary threshold' which may start these tipping cascades may be as low as 2°C above pre-industrial levels – which conveniently corresponds to the ambition expressed in the Paris Agreement to limit warming to "well below 2°C above pre-industrial levels" (United Nations, 2015, p. 3).

Steffen et al. (2018) argue that humanity is at a crossroads and has a choice to make. Continuing as usual will all but certain result in crossing the planetary threshold, eventually leading to a 'Hothouse Earth' regime. However, if humanity actively seeks to manage the planetary system through Earth System Stewardship, that is, "deliberate decisions to […] maintain the Earth System in Holocene-like conditions" (Steffen et al., 2018, pp. 8255-8256), Earth may be stabilized in a regime that is conducive to human, floral, and faunal wellbeing (Figure 7). In this way, the article is somewhat of a call to action.

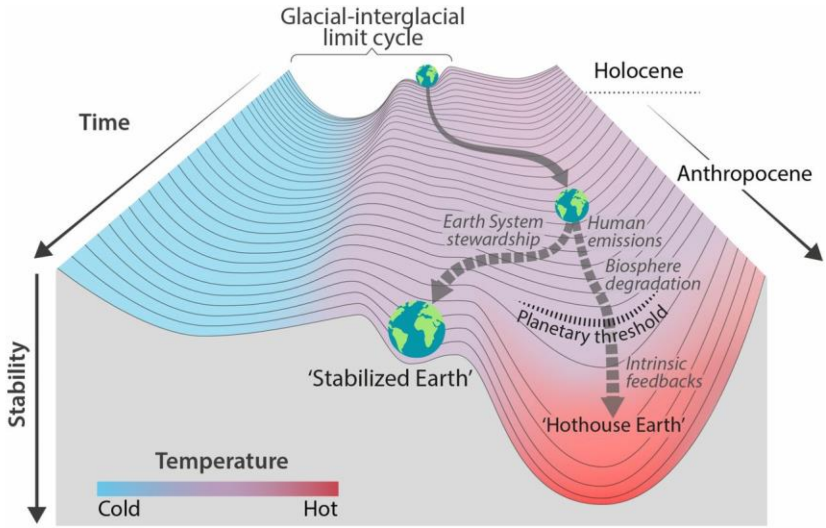

Figure 7. Stability landscape of the Earth System. The continuous arrow shows the Earth System's pathway out of the Holocene to its present position in the Anthropocene. The broken arrows show two potential pathways of the Earth System in the future. From Steffen et al. (2018, p. 8254).

The suggestion that the planetary threshold may be at 2°C above pre-industrial levels is theoretically well-founded (tipping points are well documented and cascading is possible) but not clearly calculated: the location of the planetary tipping point at 2°C is a 'suggestion' (Williamson, Rapley, & Siegert, 2018). Climatologist Richard Betts (2018) also expresses his appreciation of the overall paper, but emphasises the importance of nuancing the 2°C threshold – there is massive uncertainty about the location of a planetary tipping point related to temperature increase, if it exists at all. The location at 2°C is absolutely not set in stone. Furthermore, it is suspiciously convenient in that the threshold aligns with the Paris Agreement target. The aim of Steffen et al.'s article appears to be to inspire governments to commit to ambitious mitigation policy. The argument that there is a planetary tipping point at exactly 2°C above pre-industrial levels should be taken with a pinch of salt. It is entirely possible that the planetary tipping point, if it exists, is at a higher temperature, or worse, that it has already been crossed.

In addition to the earlier discussed consequences of climate change and the risk of climate tipping points, the possibility of a planetary tipping point raises the stakes even further. This is a matter of intergenerational justice: the actions of the present generation can set in motion an irreversible change that will harm future generations. The next chapter will explore the implications of climate tipping points for intergenerational justice. I will argue that a minimal theory of intergenerational justice based on widely held assumptions will lead to the conclusion that climate tipping points must be avoided. This conclusion will, by extension, also hold for more ambitious or more stringent theories of intergenerational justice. Additionally, sustainability is redefined. Sustainability is considered a necessary condition for intergenerational justice, but whereas some understand this to mean the maximum indefinite return of one variable, a resilience perspective recognises that the ability of a system to absorb disturbances is necessary for sustainability. This, in turn, implies that the stability of the overall Earth system is a necessary condition for intergenerational justice.

3. Intergenerational justice and sustainability

Building on the discussion of resilience theory and climate tipping points given in the previous chapter, this chapter will discuss two main issues. In Section 3.1, the argument is made that an uncontroversial, baseline theory of intergenerational justice leads to the conclusion that climate tipping points must be avoided. This is based on a general review of the literature on intergenerational justice, and an overview of the literature on climate change and intergenerational justice, both of which are provided in the same section. The baseline requirement of intergenerational justice is defined as granting future generations the opportunity to meet their basic needs.

In Section 3.2, the relation between sustainability, resilience, and intergenerational justice is discussed. It is argued that sustainability is a necessary condition for intergenerational justice. In the intergenerational justice literature, sustainability is often understood as ensuring that one outcome (e.g. utility or welfare) can be provided indefinitely. The resilience perspective is different. Resilience does not aim for any one outcome, but rather it emphasises the importance of fostering the ability of systems to cope with disturbance and change. Resilience is a necessary condition for sustainability. Since sustainability requires resilience, and intergenerational justice requires sustainability, system resilience is a necessary condition for intergenerational justice. Earth System Stewardship is the academic discipline that explores how mankind could foster the resilience of the Earth System in a regime that is conducive to human well-being. Given that a stable Earth is needed to provide future generations with the opportunity to meet their basic needs, Earth System Stewardship should be a priority for intergenerational justice.

3.1 Intergenerational justice and climate tipping points

This section will first introduce intergenerational justice in general, and formulate a baseline theory of intergenerational justice. This baseline holds that future generations should have the opportunity to meet their basic needs. Next, a succinct overview is provided of climate change in the intergenerational justice literature. To the best of my knowledge, no philosophical account has discussed the implications that climate tipping points may have for intergenerational justice. In the final paragraph of this section, I discuss the implication of climate tipping points for intergenerational justice. I reach the conclusion that intergenerational justice requires that we do not cross climate tipping points, because crossing climate tipping points diminishes the ability of future generations to meet their basic needs.

Intergenerational justice

Justice is a term that is typically reserved for distributive matters. It is invoked when discussing competing claims between different people – for example, when searching for a just distribution of rent in a shared apartment where the different rooms vary in size. Intergenerational justice explores what justice-based claims future generations may have of the present generation. A key difference to understand is that between intragenerational justice and intergenerational justice. The former concerns justice *within* a generation; for example the current inequality between developing countries and developed countries. The latter concerns justice *between* different generations across time. Some theorists also incorporate intragenerational justice in their discussions on intergenerational justice, but strictly speaking they are different discussions. Intergenerational justice is based on the observation that the consequences of actions by the current generation will be felt by later generations. It is those issues that intergenerational justice seeks to address. In the words of Clark Wolf (2005, p. 282): "a theory of intergenerational justice would be a somewhat general background theory that would explain the justification, nature, and content of our obligations (if any) to future generations." This section will first argue that intergenerational justice is possible because all humans have equal moral worth regardless of when they are born. Next, an overview is provided of the debate on *what* exactly intergenerational justice concerns, and *how much* it should provide to future generations. I end up formulating a baseline theory of intergenerational justice, which requires that future generations have the opportunity to meet their basic needs.

Firstly, I'd like to introduce the relatively uncontroversial premise that different people have equal moral standing[3], and that there should be no morally relevant difference based on, for example, the colour of one's skin, the country in which one is born, or the time at which one is born. This implies in the words Barry (1999, p. 100), that "place and time do not provide a morally relevant basis on which to differentiate the weight to be given to the interests of different people." This notion of moral universalism is so fundamental that it is difficult to provide a justification for it that is not self-referential, but I believe that it is intuitively attractive, and, as Barry (1999, p. 100) notes, it has "an immense rational appeal." The principle entails that the time in which one is born has no moral relevance. For example, if we accept that slavery is morally wrong, it was as morally wrong in Ancient Greece, as in the 18th century United States, as in the present, as in the future. In the context of intergenerational justice, this idea of universalism implies that the generation in which one is born is irrelevant, which opens up the possibility for justice-based demands of the present generation on behalf of future generations.

Accepting the premise that there is no moral difference between the people of different generations is little more than a starting point for intergenerational justice. The basic structure of most theories of intergenerational justice is that there is some variable, X, that is to be distributed among generations (Barry, 1999). There is significant debate on *what* exactly intergenerational justice should provide – what exactly that variable X should be. Classical utilitarians would put

[3] There are several authors that also ascribe value to animals or inanimate nature (Cochrane, 2006; Singer, 1974). I am not unsympathetic to these arguments, but since the aim of this thesis is to provide a baseline theory of intergenerational justice, only human interests are considered.

utility or welfare in the place of this X; every generation should receive as much utility as possible (Mill, 1863). Inspired by Sen and Nussbaum, Robeyns (2017) argues that intergenerational justice should ensure that people have access to certain capabilities. This illustrates that there are diverse approaches, and that the debate is far from settled.

Brian Barry suggests filling in the X with the opportunity for future generations to live good lives, or more specifically, he suggests that we "provide future generations with the opportunity to live good lives according to their conception of what constitutes a good life" (Barry, 1999, p. 104). Barry's understanding of intergenerational justice remains vague, and he confesses "that saying this is not doing a lot more than set out an agenda for further study" (Barry, 1999, p. 104). However, he does argue that the opportunity given to future generation will almost certainly include passing on the ability to meet some vital interests: "we can be quite confident that it will not include the violation of what I have called vital interests: adequate nutrition, clean drinking water, clothing and housing, health care and education, for example" (Barry, 1999, p. 105). This has some parallels with sufficientarianism as defined by Lukas Meyer[4]. Put very concisely, sufficientarianism holds that everybody should live above a certain lower limit, or sufficiency threshold (Meyer, 2016). A simplified example can illustrate the sufficientarianist's point. When applied to income, sufficientarianism holds that everybody should have an income at or above a certain threshold. This generally implies, in the words of Roger Crisp (2003, p. 758), that "absolute priority is to be given to benefits to those below the threshold." If there are people who live below the threshold, their demands trump those of people who already live above the threshold. It should be noted that sufficientarianism is not egalitarian. It advocates that everybody should live on or above a certain threshold, but what happens above that threshold is deemed irrelevant. As long as all minimal needs are taken care of, it can allow for great inequalities in how far people live above the sufficiency threshold. A common criticism of sufficientarianism is that it is very difficult to define such a threshold, and that any threshold set would inevitable be an arbitrary standard (Arneson, 2000). However, it is at least theoretically a strong baseline.

Many theories go further than the sufficientarianist. The question of *how much* of the variable *X* we should provide to future generations is at least as contentious as the question of *what* the variable *X* should be. Wolf (2005) argues that intergenerational justice requires that every generation leaves the Earth for the next generation in at least the same state as it was given it – preferably in an even better state. Barry (1999) reasons along similar lines: he argues that since future generations are not responsible for the situation they find themselves in (i.e. no generation is responsible for the state of the planet it inherits), we should ensure that they are not

[4] While there are parallels, Meyer's sufficientarianism is different from Barry's theory. Whereas Meyer considers the meeting of certain minimal needs to be the requirement of intergenerational justice, Barry argues that future generations should have the opportunity to live good lives - vital interests are only a starting point for Barry.

worse off than we are. I am not unsympathetic to these arguments, but they are quite far-reaching. It is very possible to disagree with the argument that we should leave the Earth in the same state or a better state – critics could argue that the only requirement is that future generations are able to meet their basic needs (e.g. Meyer, 2016). This has similarities with the famous understanding of sustainable development as meeting "the needs of the present without compromising the ability of future generations to meet their needs" (Brundtland, 1987, p. 43). Inspired by this, I would suggest a variation on Barry's principle that is slightly less stringent. I suggest that intergenerational justice requires that we provide future generations with the opportunity to meet their basic needs, where these basic needs constitute the minimum threshold as per sufficientarianism. These basic needs are not explicitly defined, but in line with Barry's account of vital interests they are likely to include at least access to clean drinking water, adequate nutrition, housing, clothing, and health care, among others. This differs from Meyer's sufficientarianism: whereas Meyer speaks of the fulfilment of certain minimal needs, this formulation merely speaks of the opportunity to fulfil those minimal needs.

To summarize: the strength of Barry's conception of intergenerational justice is its generality. It does not yet define what exactly future generations will want. It is entirely possible that the needs of future generations will be different from those of the present generation. Barry merely notes the necessity to provide future generations with the freedom to achieve what they will want to achieve, and that this requires that at least some vital interests remain unspoiled (Barry, 1999). I provide a variation on this, inspired by sufficientarianism. Instead of Barry's argument that intergenerational justice requires that future generations can live good lives according to their conception of what constitutes a good life, I take a less stringent approach and argue that future generations should have the opportunity to meet their basic needs. This is not to say that there is no merit in theories of intergenerational justice that set higher targets. My aim here is to provide a baseline theory of intergenerational justice that is somewhat general and uncontroversial. If this theory leads to significant conclusions, these conclusions would likely also hold for more stringent theories of intergenerational justice. This is because the opportunity for future generations to meet their basic needs is a necessary condition for other theories of intergenerational justice. For example, the fulfilment of the utility-based demands of intergenerational justice requires that the opportunity to achieve this utility is given – but not the other way around. Anyone who argues for an account of intergenerational justice invoking notions of utility needs to provide future generations with the opportunity to meet their basic needs – this opportunity is a necessary condition to provide the utility. However, utility goes beyond opportunity, and already defines what exactly future generations should want (in this case, maximum utility). As noted before, I am looking for a baseline theory of intergenerational justice.

Providing future generations with the opportunity to meet their basic needs is a necessary condition for any convincing theory of intergenerational justice.

Based on the premise that different people have equal moral worth and the premise that time is a morally irrelevant factor, I have argued that future generations can have justice-based claims on the present generation. I have introduced the debate around what exactly the variable is that intergenerational justice seeks to address, and how much of this variable should be provided to future generations. I argue in favour of a variant of Barry's (1999) argument, who claims that intergenerational justice should provide future generations with the opportunity to live good lives according to their conception of what is a good life. Inspired by Brundtland (1987) and Meyer (2016), I redefine this as the opportunity for future generations to meet their basic needs. This conception is particularly attractive because it is more general and fundamental than other theories of intergenerational justice. Practically every theory of intergeneration justice requires the opportunity for future generations to meet their basic needs: this opportunity is a necessary condition for those who prefer utility and those who prefer capabilities alike. This generality is not a weakness, but a strength. If a theory that only considers the opportunity of future generations to meet their basic needs leads to certain conclusions, it is likely that those conclusions will also hold for more stringent theories of intergenerational justice.

In the following paragraph a concise overview of the literature on climate change and intergenerational justice is provided. Although much has been written on the topic, there is to the best of my knowledge no philosophical work that combines climate tipping points with intergenerational justice. In the paragraph after next, I'll discuss the implications of climate tipping points and argue that intergenerational justice requires that we do not cross climate tipping points.

Climate change and intergenerational justice

Climate change is an archetypical intergenerational justice problem. The actions of the present generations (e.g. greenhouse gas emissions) determine the kind of world that future generations will inherit. The unique ethical challenges that climate change presents has inspired Gardiner (2006) to describe it as 'a perfect moral storm.' One important way in which climate change is uniquely intergenerational is the fact that it is a severely lagged phenomenon: changes instigated now are not felt until many years later. This inertia of the Earth System was mentioned in Chapter 2 in relation to climate tipping points. The North Pole may already be heading to a summer without sea ice – it just takes time for this to materialise (Serreze, Holland, & Stroeve, 2007). Eventual sea level rise may be in excess of 25 meters above current levels, but it takes a long time for this change to be realised (Steffen, 2011). The thawing of permafrost, and particularly the forming of lakes which further accelerate thaw, appears irreversible (Anthony et al., 2018). Although Gardiner does not discuss tipping points, he accurately notes that the fact that climate change's consequences are delayed entails that "the bad effects of current emissions are likely to fall, or fall disproportionately, on future generations, whereas the benefits of emissions accrue largely to the present" (Gardiner, 2006, p. 404). This is troublesome, because current generations may prioritize current interests over future interests. In a later article, Gardiner (2017) called this 'the tyranny of the contemporary.' All of this put together, according to Gardiner, makes people very vulnerable to moral corruption (i.e. people are likely to shirk their moral responsibility and neglect to do what morality requires).

Although Gardiner gets close by discussing the time lagged aspect of climate change, he does not explicitly discuss tipping points. Most of the literature on intergenerational justice appears to implicitly assume linear warming – or at least predicable warming (Shue, 2014). Other articles are more concerned with specific justice-related questions. For example, Simon Caney provides an interesting critique of the polluter pays principle, and notes that despite its popularity it is flawed since not all polluters can be made to pay (e.g. deceased polluters). Hence, the polluter pays principle is incomplete (Caney, 2005). All of these articles are interesting, but to the best of my knowledge there is no philosophical literature on intergenerational justice that fully appreciates climate tipping points. Scholars still implicitly take a linear perspective of climate change. Of course, even from a linear perspective climate change is a massive challenge of intergenerational justice, but the irreversibility of climate tipping points raises the stakes and can change the debate. As opposed to the linear perspective of climate change, the crossing of tipping points can start irreversible feedback loops that push the Earth system into a new regime, and this new regime may make intergenerational justice much harder or even impossible to achieve.

Climate tipping points and intergenerational justice

As discussed in Chapter 2, a core issue of tipping points is that they can be irreversible. Once a system is heading towards a different state, it can be impossible to pull it back into its original regime. This significantly raises the stakes, and warrants the use of a precautionary principle (i.e. since the consequences of crossing tipping points are so harmful, preventative action is justified even in the absence of complete certainty of where exactly the tipping point is located). I argue that the threat of climate tipping points implies that intergenerational justice requires that climate tipping points must be avoided. This argument is based on the simple syllogism given in Figure 8.

Premise 1: Intergenerational justice requires that every generation has the opportunity to meet their basic needs.

Premise 2: If climate tipping points are crossed, future generation's ability to meet their basic needs is diminished.

Conclusion: Intergenerational justice requires that we do not cross tipping points.

Figure 8. Intergenerational justice requires that we do not cross tipping points.

The first premise is based on what has been discussed earlier in this section. The case has been made that every generation should have the opportunity to meet their basic needs. This is inspired by Barry's (1999) discussion of intergenerational justice; by Meyer's (2016) explanation of sufficientarianism; and by Brundtland's (1987) understanding of sustainable development. The argument that intergenerational justice requires that every generation has the opportunity to meet their basic needs is a minimal requirement: it is very possible to argue for more ambitious theories of intergenerational justice, but it is very difficult to argue that this requirement goes too far.

The second premise is broadly based on Chapter 2. As has been discussed more in depth there, the crossing of tipping points tends to be irreversible. The current ecosystem is very supportive to human life, and hence the opportunity for humans to meet their basic needs. The system changes that are expected with continued climate change would result in an Earth System that is much less conducive to human life and that is dangerous in several ways. Several studies note the impact of climate change on dimensions such as food yields and water supplies, which are expected to reduce under pressure of more extreme weather events and droughts (USGCRP, 2018; IPCC, 2014; 2018; WMO, 2019). This directly affects the basic needs of food security and access to clean drinking water. Furthermore, sea level rise will eventually drive people who live in coastal regions out of their homes (Steffen, 2011). Other areas will become so hot, that they will literally become uninhabitable (Pal & Eltahir, 2016). This will result in people struggling to fulfil their basic need of housing. More generally, the rapid change that is associated with regime shift is difficult to maneuver for humans and other animals who are caught up in it. The new regime that the Earth System may end up in can be, and likely will be, much less conducive to human life than the temperate conditions of the Holocene over the past 10,000 years (Steffen et al., 2018). All of this supports the premise that the crossing of climate tipping points would diminish the ability of future generations to meet their basic needs.

Current science is unable to pinpoint where exactly climate tipping points are located. Suggestions, such as the suggestion that a planetary tipping point is located at 2°C above pre-industrial levels (Steffen et al., 2018), are rightly criticised for providing insufficient substantiation for locating the tipping point at that exact temperature (Betts, 2018; Williamson, Rapley, & Siegert, 2018). However, this scientific uncertainty should not lead to inaction. Given that the consequences of crossing climate tipping points are so massive, it is wise to adopt a precautionary principle and to err on the side of caution. Invoking the precautionary principle means that preventative action is warranted while this uncertainty persists. Even without knowing the exact location of climate tipping points, preventative action is warranted to reduce the risk of crossing these climate tipping points.

Lastly, combining both premises we reach the conclusion that intergenerational justice requires that we do not cross tipping points. This is a syllogism: if we accept that intergenerational justice requires us to provide future generations with the opportunity to meet their basic needs; and we accept that the crossing of climate tipping points will diminish the ability of future generations to meet their needs; we reach the conclusion that intergenerational justice requires that climate tipping points are not crossed.

3.2 Resilience theory and sustainability

The previous section has found that intergenerational justice requires that climate tipping points are not crossed. Although that finding already has strong implications for today's world, it is in fact only an iteration of an underlying logic. That underlying logic is that sustainability is a necessary condition for intergenerational justice, and that system resilience is essential for sustainability. The earlier discussed climate tipping points are an exceptionally salient iteration of this underlying logic, but the general argument is broader: system resilience is a necessary condition for intergenerational justice.

The connection between sustainability and intergenerational justice should now be clear. The previous section started with the premises that different people have equal moral worth and that time is a morally irrelevant factor. If we accept these premises, it follows that different generations of people have equal moral worth. There is no compelling reason to expect the accretion of new generations to end anytime soon. This entails that we must act on the assumption that mankind will keep existing, which has implications for intergenerational justice. In theories of intergenerational justice, there is typically some variable X that should be maintained so that future generations can enjoy said X. This implies that the enjoyment of variable X should be sustainable: every generation should be able to enjoy it, and since we have no reason to expect a stop in the accretion of new generations, the ability to enjoy variable X should be maintained indefinitely. Intergenerational justice requires that the stock of X, whatever it may be, should never run out. This has led Barry (1999) to conclude that sustainability is a necessary condition for intergenerational justice.

Sustainability in this context can thus be understood as ensuring that the requirements of intergenerational justice can be met indefinitely. This is concerned with an outcome or result: the requirement of intergenerational justice must be achieved. But, as will be detailed in the following paragraph, resilience theory teaches that focussing on the optimization of certain outcomes is dangerous. Focussing on specific outcomes can make systems homogenous and vulnerable to disturbance. Once inevitable disturbances come, the entire system is more likely to collapse. Resilience theory emphasises the importance of adaptive capacity: the ability of a system to absorb disturbances and persist while maintaining essentially same identity or regime. As long as the system remains in the same regime, it will provide certain outcomes, but the focus of resilience is explicitly *not* on the outcomes but rather on the resilience and stability of the overall system. In the words of Redman (2014, p. 37): "sustainability prioritizes outcomes; resilience prioritizes process." Put differently: resilience is a property of systems. Systems can be more resilient or less resilient. Only resilient systems can persist, and provide sustainable outcomes (Elmqvist, 2017). Since sustainability is a necessary condition for intergenerational justice, and system resilience is a necessary condition for sustainability, system resilience is also a necessary condition for intergenerational justice.

This section is divided into two paragraphs. The first paragraph will detail the implications of resilience theory for the sustainability component of intergenerational justice. System resilience is a necessary condition for sustainability – where sustainability is understood as the ability to indefinitely provide future generations with the opportunity to meet their needs. This implies that system resilience is a necessary condition for intergenerational justice. The second paragraph will introduce Earth System Stewardship. In the Anthropocene, the Earth System's resilience seems to be eroding. But mankind's great influence over Earth may be used to improve its resilience. Earth System Stewardship is the discipline that explores how mankind can actively seek to ensure the system remains in a resilient regime that is conducive to human wellbeing. The relation between Earth System Stewardship and intergenerational justice is discussed.

The resilience perspective of sustainability

As discussed more extensively in Chapter 2, resilience is the capacity of a system to absorb change and disturbance while maintaining essentially the same overall form (Holling, 1973; Walker & Salt, 2006). A crucial aspect is that the system can self-organize to retain the same identity. Given that systems are constantly facing changes and disturbance, resilience is "the capacity of a system to absorb disturbance and reorganize so as to retain essentially the same function, structure, and feedbacks – to have the same identity" (Walker & Salt, 2012, p. 3).

In the context of intergenerational justice, I have defined sustainability as that there is some variable which intergenerational justice requires to be provided ad infinitum, to all future generations. A natural response would be to focus on that variable, and try to optimize it. Resilience theory warns against that impulse. Optimizing the return of one variable while ignoring the system more often than not leads to reduced resilience and can, by extension, result in harmful consequences up to system collapse. Homogenous systems designed to optimize the return of one variable are vulnerable: "success in controlling a narrow set of parameters may lead to surprising, and often adverse, outcomes in the broader system" (Folke et al., 2016, p. 41). This point can be illustrated with an example. A farm that only grows one type of banana may be highly optimised, and save costs by only harvesting this one type of produce. However, this optimisation makes it vulnerable to disturbance. Resilience theory posits that disturbance is inevitable, and this banana farm may be vulnerable to a drop in banana prices, or a disease that specifically targets bananas.

Experts on resilience theory all emphasize the importance of diversity and redundancy for resilience (e.g. Biggs et al., 2012; Walker & Salt, 2006; 2012). Diversity and redundancy in a system allows for it to bounce back from disturbances. If all the system's eggs are in one basket, any disturbance to eggs immediately affects the whole basket. A diverse basket, with eggs, bread, bananas, and cheese, is more resilient.

Optimizing one variable can lead to reduced resilience, and can make a system more vulnerable to collapse. The approach to intergenerational justice set out in the previous section, that intergenerational justice requires that future generations are granted the opportunity to meet their basic needs, does not fall into this trap (or at least not immediately). The opportunity of future generation to meet their basic needs hinges on them living in an Earth System that is conducive to meeting these basic needs. As discussed before, Holocene-like conditions are very supportive to human well-being. An Earth System disturbed by climate change can end up in a regime that makes it much more difficult to fulfil basic human needs (Steffen et al., 2018). Sea level rise and temperature increase can make areas that are currently thriving, uninhabitable (Steffen, 2011; Pal & Eltahir, 2016). Droughts and extreme weather events can affect food supplies and the availability of clean drinking water (IPCC, 2014; 2018). In order to ensure that future generations have the opportunity to meet their basic needs, the Earth System must stay in a regime that is supportive to humans meeting their basic needs. The resilience of this regime must be fostered.

This leads to the conclusion that sustainability, which is understood to mean ensuring that certain desirable outcomes are achieved indefinitely, requires system resilience. Williams et al. (2017) even go so far as to reduce the entire concept of sustainability to resilience, redefining it as follows: "sustainability is the ability of the systems to persist, adapt, transform or transition in the face of constantly changing conditions" (Williams et al., 2017, p. 871). In line with Redman (2014) and Elmqvist (2017), I keep the two concepts separate. Resilience is a descriptive property of systems: systems can be more resilient or less resilient. Sustainability is a normative concept, which posits that certain outcomes should be provided indefinitely.

This leads to the conclusion that system resilience is a necessary condition for intergenerational justice. This is notably *not* a set state that can be reached: "resilience is not about not changing" (Walker & Salt, 2012, p. 25). Rather, it is about bouncing back up from a disturbance in the same way. If, for example a small bushfire destroys a part of a forest, the surviving saplings and seeds ensure that a similar forest returns. This is of course not the exact same forest, but it is similar enough to speak of one continuing forest – the system does not change states and move into a different regime, it is still a forest (Walker & Salt, 2006). Sustainability requires that a system persists in the same regime. In order to achieve the sustainability that intergenerational justice requires, the systems that provide humanity with the opportunity to meet their basic needs must be resilient.

If we accept the earlier defined requirement of intergenerational justice (i.e. that we must grant future generations the opportunity to meet their basic needs), it follows that we must seek to maintain the Earth System in a regime that allows humanity the opportunity to meet its basic needs. A stable climate that does not endanger the opportunity of future generations to meet their basic needs is a prerequisite for intergenerational justice. The Earth System must be in a resilient regime, and that regime must provide future generations the opportunity to meet their needs. The following paragraph will discuss Earth System Stewardship, which is an academic discipline that explores how mankind can foster the resilience of the systems on which it depends.

Earth System Stewardship

The previous paragraph showed that system resilience is a necessary condition for intergenerational justice. As discussed more extensively in Chapter 2, the current trajectory of the Earth system is a cause for concern. Due to human activities, the resilience of Earth's current regime is being eroded. We have already left the Holocene and seem to be heading towards a regime that is far less conducive to human life. This is especially concerning for intergenerational justice, since the ability of future generations to meet their basic needs hinges on them living in an Earth system that provides them with the opportunity to meet their basic needs. Mankind has a massive influence on Earth, and will determine the future of this planet. Could this influence not be used for good? Eighteen years ago, C.S. Holling argued that based on resilience theory it seems possible "to identify the points at which a system is capable of accepting positive change and the points at which it is vulnerable. It then becomes possible to use those leverage points to foster resilience and sustainability within a system" (Holling, 2001, p. 392). In other words: it should theoretically be possible for humanity to foster the resilience of the systems on which it depends. This is currently a frontier of science, known as Earth Stewardship (Chapin et al., 2011), Biosphere Stewardship (Folke et al., 2016), or Earth System Stewardship (Steffen et al., 2018) All three terms refer to very similar ideas. I will use the term Earth System Stewardship, since this explicitly verbalizes the importance of fostering the resilience of the entire, overarching system. This paragraph will introduce the core tenets of Earth System Stewardship and explore its relation to intergenerational justice.

The core logic of Earth System Stewardship is, according to an early definition, that humanity takes an active role in the "shaping of trajectories of change in coupled social-ecological systems at local-to-global scales to enhance ecosystem resilience and promote human well-being" (Chapin et al., 2011, p. 45). In the words of Folke et al. (2016, p. 41), it "integrates reducing vulnerability to expected changes, fostering resilience to sustain desirable conditions in the face of perturbations and uncertainty, and transforming from undesirable trajectories when opportunities emerge." Steffen et al. (2018, pp. 8255-8256) define it as "deliberate decisions to […] maintain the Earth System in Holocene-like conditions." I would summarize it as follows: Earth System Stewardship holds that humanity should take an active role in trying to ensure that the Earth System is in a resilient regime that is conducive to the opportunity for humanity to meet its basic needs.

Earth System Stewardship recognizes the massive impact mankind has on Earth. Rather than feign ignorance about the impact of its actions, mankind should try to use its influence for good, and to foster the resilience of the systems on which humanity depends. This may be normatively appealing, but it is much more complicated in practice. Fostering resilience is a complex and difficult thing. However, recent research has identified several principles which can provide a good starting point.[5] More detailed discussions of these principles can be found in the works of Walker and Salt (2006); Biggs et al. (2012); and Carpenter et al. (2012). Here, I'll briefly introduce the principle of diversity and redundancy, and the principle of modularity (also known as connectedness).

First, diversity and redundancy, which has already been touched upon earlier in this thesis, is a key factor. If an external disturbance affects one component of a system, other elements that perform similar functions as the affected component can jump in and make sure that the system persists in the same regime. If, for example, a flower patch is pollinated by both bees and hummingbirds, a disturbance that decimates the population of bees does not lead to a stop in pollination: hummingbirds still fulfil that ecosystem service. Second, modularity or connectedness denotes the degree to which separate parts of a system interact. Highly interconnected system are less resilient: a disturbance on one end of the system can quickly spread throughout the whole system. For example, in today's globalized economy, there is serious concern that a disease that is affecting banana plantations throughout Australia, Africa, and south-east Asia, could spread to Latin America and damage the global supply of bananas. If parts of a system are insulated, this can enhance resilience since disturbances are less likely to spread and affect the entire system. With both principles, though, it is a matter of degree. Homogenous systems are vulnerable to disturbance, but diverse systems are highly complex and inefficient. Highly connected systems can allow for disturbances to spread, but they can also facilitate quick recovery after a disturbance (Biggs et al., 2012). More detailed discussions of principles that contribute to system resilience can be found elsewhere (e.g. Walker & Salt, 2006; Biggs et al., 2012; Carpenter et al., 2012). All of

[5] The principles found in the literature include diversity, ecological variability, modularity, acknowledging slow variables, tight feedbacks, social capital, innovation, overlap in governance, and ecosystem services (Walker & Salt, 2006); maintain diversity and redundancy, manage connectivity, manage slow variables and feedbacks, foster an understanding of social-ecological systems as complex adaptive systems, encourage learning and experimentation, broaden participation, and promote polycentric governance systems (Biggs et al., 2012); and diversity, modularity, openness, reserves, feedbacks, nestedness, monitoring, leadership, and trust (Carpenter et al., 2012).

these principles remain somewhat general: "the wide-ranging nature of general resilience makes it difficult to define specific steps for creating it. Instead it is possible to identify conditions that can enable or support the development of general resilience" (Carpenter et al., 2012, p. 3251). Still, these general principles can prove helpful in moving forward with Earth System Stewardship.

To summarize: current trends (especially with regards to climate change) suggest that in the future humanity may struggle to meet its basic needs (Pal & Eltahir, 2016, IPCC, 2018, USGCRP, 2018; WMO, 2019). In order to ensure that the requirement of intergenerational justice (understood as providing future generations with the opportunity to meet their basic needs) can be met sustainably, the Earth must be in a resilient regime that is conducive to human wellbeing. Earth System Stewardship is the frontier of science that seeks to explore how exactly mankind can foster the resilience of the systems on which we depend. Although the general principles that the Earth System Stewardship literature has found thus far remain somewhat theoretical, they can provide a starting point in the pursuit of intergenerational justice.

4. Conclusion

This fourth and final chapter will provide a concise overview of the findings of this thesis. This thesis has found that the minimal requirement of intergenerational justice is that future generations have the opportunity to meet their basic needs; that the crossing of climate tipping points diminishes the ability of future generations to meet their basic needs; and that therefore intergenerational justice requires that climate tipping points are not crossed. Furthermore, this thesis has found that sustainability is a necessary condition for intergenerational justice; that system resilience is a necessary condition for sustainability; and that therefore the stability of the Earth System in a regime that is conducive to humanity meeting its basic needs is a necessary condition for intergenerational justice. Earth System Stewardship is an area of research that explores how mankind can foster the resilience of the systems on which we depend, and this would be a good area to draw lessons from in the pursuit of intergenerational justice.

4.1 Findings

Today, mankind is the most influential force on Earth. Climate change is one of the greatest issues of this Age of Man, of the Anthropocene. Recent research has found that there are ecosystems that can suddenly change due to anthropogenic warming. This system change is irreversible and these climate tipping points will further amplify warming – thereby locking in a dangerously warmer future. This presents a novel challenge to intergenerational justice, and particularly the sustainability component of intergenerational justice. All of this inspired the following research question:

What are the implications of climate tipping points and resilience theory for intergenerational justice, and for the sustainability component of intergenerational justice?"

In the course of this thesis, this question has been answered. In Chapter 2, climate tipping points have been introduced, building on an understanding of climate change and resilience theory. The concentration of greenhouse gasses such as CO_2 in the atmosphere has skyrocketed, and this is causing the planet retain solar heat more efficiently – it is thus warming the planet. Resilience theory teaches that systems typically exist in a relatively stable regime, and can absorb disturbances. Once the disturbances are too great, however, the system can suddenly collapse and find itself in another regime. As the planet warms, local systems experience reduced resilience and regime changes. These new regimes can further amplify warming. Several of these climate tipping points have been introduced. Climate tipping points are particularly dangerous because they are irreversible. As several local systems cross tipping points, the possibility exists that a planetary tipping point could be crossed, at which the tipping of several local elements causes the tipping of other elements, until the entire Earth System is heading towards a new regime.

In Chapter 3, a baseline theory of intergenerational justice was formulated. The debate on intergenerational justice is far from settled, but I argue that virtually all theories would agree that future generations should have the opportunity to meet their basic needs – this is a necessary condition for any convincing theory of intergenerational justice. When this minimal requirement is combined with the reality of climate tipping points, it follows that intergenerational justice requires that climate tipping points are not crossed. This argument holds because the crossing of climate tipping points will diminish the ability of future generations to meet their basic needs. Given the current state of the planet, this conclusion has major implications. To avoid crossing climate tipping points, immediate and large-scale mitigation is needed.

In Chapter 3, the relation between sustainability, resilience, and intergenerational justice was discussed. Sustainability, understood as ensuring that certain outcomes are provided indefinitely, is a necessary condition for intergenerational justice. However, it is important not to focus only on those outcomes. Resilience theory teaches that focussing on one variable while ignoring the overall system typically leads to unintended consequences. Rather, it is important to foster the capacity of a system to absorb various disturbances while maintaining the same overall form or structure. Homogenous, optimized systems are typically not resilient. This implies that maintaining the resilience of the systems that allow humanity to meet its basic needs is a necessary condition of intergenerational justice. “Maintaining the resilience of the systems that allow humanity to meet its basic needs” is easier said than done. Earth System Stewardship is the area of research that investigates how humanity can foster the resilience of the systems on which it depends. It has identified several general principles which can improve system resilience (e.g. diversity and modularity). Although these principles remain somewhat theoretical, knowledge and understanding of Earth System Stewardship is a good starting point in the pursuit of a resilient Earth System, which is a necessary condition for intergenerational justice.

The research question can thus be answered. The baseline theory of intergenerational justice formulated in this thesis requires that climate tipping points must be avoided. This conclusion will likely also hold for other theories of intergenerational justice, since those theories are more stringent than the baseline formulated here. The implication of resilience theory for the sustainability component of intergenerational justice is that system resilience is a necessary condition for sustainability. Since sustainability is a necessary condition for intergenerational justice, system resilience is also a necessary condition for intergenerational justice. Earth System Stewardship is the area of research that can provide a starting point in the pursuit of this resilience. It is important to add a caveat to these conclusions. This thesis has primarily made normative arguments about what is required to achieve intergenerational justice. Current system trends suggest that the situation is quite dire. Immediate action is needed to avoid crossing the climate tipping points that could put intergenerational justice out of reach.

4.2 Contribution and further research

This thesis has contributed to existing literature in several ways. First of all, it is, to the best of my knowledge, the first philosophical work to combine climate tipping points with intergenerational justice. Although previous accounts of intergenerational justice and climate change exists, there is to the best of my knowledge no literature that specifically focusses on the implications of climate tipping points for intergenerational justice. Second, a minimally controversial baseline theory of intergenerational justice was formulated. The requirement of this theory is that future generations are granted the opportunity to meet their basic needs. This is a minimal requirement, and many theories of intergenerational justice are more stringent. However, the conclusions that hold for this baseline theory will very likely also hold for more stringent theories. Third, the relation between sustainability and resilience was discussed. This has been done before in the literature on ecology and systems theory, but to the best of my knowledge not in the philosophical literature. This understanding of sustainability has led to the conclusion that system resilience is a necessary condition for intergenerational justice, and that Earth System Stewardship is a means of achieving this system stability. Earth System Stewardship should therefore be a priority of intergenerational justice.

On the basis of this thesis, several suggestions for future research can be made. One aspect this thesis touched upon that warrants further research is Earth System Stewardship. In the Anthropocene, the role of humans on this planet is changing. Earth System Stewardship is in need of more practical research: how exactly can humans foster the resilience of the Earth System? This would continue the research of, among others, Biggs et al., (2012). It is important that the rather abstract normative point of Earth System Stewardship is translated to practical policies. Walker and Salt (2006) argue for the shortening of feedback loops, which is ecology jargon for saying that people need to be made aware of the consequences of their actions. Currently, the cost of certain actions does not accurately reflect the cost of that action to the resilience of the Earth system. This could be alleviated by making sure that incentives are properly aligned, for example via taxes and subsidies. There is significant work on this in relation to carbon pricing (e.g. Nordhaus, 2018), but the same logic could be applied more broadly. For example, farming methods that do not erode the long-term richness and stability of the soil could be subsidised.

Besides this practical research, Earth System Stewardship is also in need of more philosophical attention. How should we think about the role of humans on the planet in the Anthropocene? Is self-imposed stewardship not an expression of human arrogance? Furthermore, Earth System Stewardship gives rise to epistemological questions: how should we account for the uncertainty associated with system dynamics? Can we justify meddling in the Earth System without knowing exactly what the consequences of our actions will be?

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Appendix

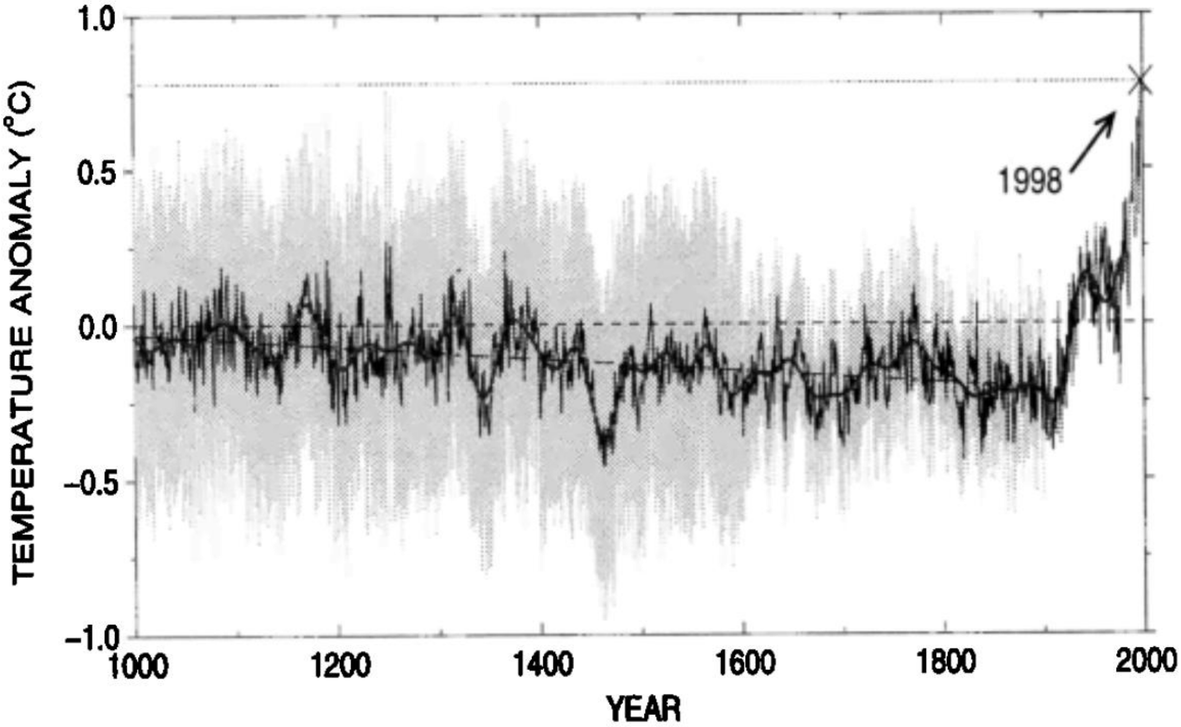

Figure 9. Temperature anomalies in the millennium 1000-2000 (Mann et al., 1999).

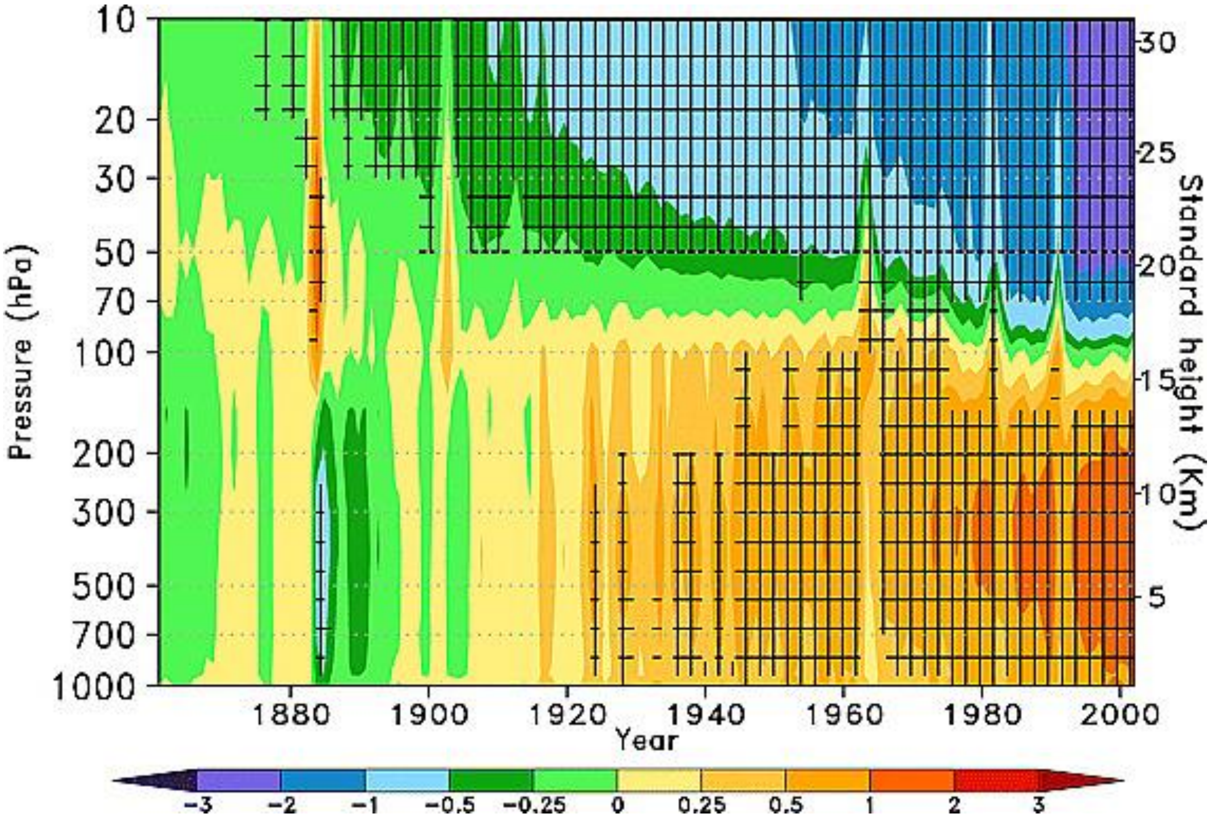

Figure 10. Temperature anomalies and altitude (Schwarzkopf & Ramaswamy, 2008).