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Social limits to climate change adaptation: temporalities in behavioural responses to climate risks

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Abstract

Social constraints and limits on adaptation are strongly influenced by the rates at which climate-influenced risks emerge and the speed of the coping response, including the pace at which adaptative changes can be made. This short review assesses how adaptation limits are shaped by extreme events, changing probabilities of extreme events under climate change, the future evolution of adaptation options and strategies, the emergence of cascading or systemic risks and historical patterns of social relations. While adaptation limits are expressed by tipping points in the behaviours of social actors, this behaviour is framed by intersecting temporalities (cultural, economic, technical and political) operating through social systems. Greater awareness of these temporalities will help improve our capacity to analyse and predict the social tipping points which are evidence of adaptation limits, improving the capacity of international and public policy to target resources at the most vulnerable.

Introduction

As climate changes, people and organisations will seek to cope and adapt. But the capacity to adapt is unlikely to be unlimited. As risks and the costs of adaptation rise for people and communities, there will likely be a point in most social and ecological systems where *social tipping points* emerge. In natural systems this could be range changes, niche shifts or extinctions of species (Grinder & Wiens, 2023; McLaughlin et al., 2002; Román-Palacios & Wiens, 2020), while in social systems this may be changes in habitability or livelihood (Horton et al., 2021; Spencer et al., 2024). An actor-centred, risk-based framework for adaptation limits (Berkhout et al., 2024; Dow et al., 2013) argues that adaptation effort by social actors (individuals, households, businesses and communities) to respond to climate-related risks increases up to a point where risks become *intolerable*. At this point, facing substantial and irreversible loss and damage, actors will be faced with a choice to make radical changes in behaviour. In/tolerability of risk will be defined by actors themselves, based on cultural norms, perceptions and decision-making practices, historical structures of social relations, and is relational and evolves over time (Pemberton et al., 2021). Adaptation limits will also be an outcome of actors actively engaging in building resilience, influencing collective definitions and shaping risk governance (Renn et al., 2018). Adaptation limits do not *happen* to people, they emerge as an historically situated and negotiated social process with many potential outcomes, including resistance to social tipping points.

Adaptation to climate risk is a process that occurs over time. An analysis of adaptation action and constraints and limits on that action therefore needs to take account of the relative rates of change, adaptability and what may be called the 'temporalities of risk and resilience' (Jackson, 2023; McMichael & Katonivualiku, 2020). This paper discusses four aspects of these temporalities. First, there is aleatory uncertainty, which refers to natural variability in weather and climate, which may be difficult to predict. Weather and climate are inherently variable, across varying timescales: from Milankovitch cycles (1000s of years) and the Schwabe sunspot cycle (about 11 years) to El Niño/La Niña cycles (2-7 years), monsoons (annual) and cyclones/anticyclones (~day). Many significant climate risks stem from extreme events (storms, floods, extreme heat events). Adaptation choices made by people will be concerned with making sense of and responding to perceived patterns and trends of these events and the losses they may generate in a particular place (Bleda et al., 2023; Tschakert et al., 2019).

Extreme events are rare, hard to predict and specific in their impacts. Evidence about their occurrence and potential impacts is likely to be scarce or conditional on wide uncertainties. Making sense and preparing for them is therefore difficult, whatever knowledges such predictions are based on (Wasko et al., 2021). Second, climate risks are being reshaped through time as a result of climate, social and technological change (Field et al., 2012) – extreme events change in frequency (Bloemendaal et al., 2022), underlying social vulnerabilities evolve (George et al., 2024) and attitudes to risk develop (Wheeler et al., 2021). In responding to changed conditions and evolving capabilities and expectations, people make judgements about whether to invest greater resources in adaptation and when (Aragón et al., 2021), including the need to anticipate and respond along pathways of adaptation (Haasnoot et al., 2020a).

Third, the availability of adaptation options may be enabled or constrained by prevailing conditions or capabilities (financial, economic, institutional or cultural) and these change over time (Thomas et al., 2021), for instance by growing wealth and resources (Klein, R J T et al., 2015) or by investments in technical and organisational innovation (Lebel et al., 2021). New adaptation options (technological, organisational or nature-based) may become available through innovation (Schinko et al., 2024). It may become easier or cheaper to adapt, extending the 'adaptation space' for social actors, even if there are deep inequalities in the availability of options and strategies to adapt and build resilience. Fourth, we can predict that with intensified and more extreme climate impacts, adaptation limits will be experienced progressively more widely, by more people, in more places, sectors and systems (Mechler et al., 2020) and that these will lead to complex interactions and feedbacks across places and spaces, supply chains, socio-technical systems, trade and exchange. There is an emerging literature on *systemic* climate risks which envisages connecting, cascading and amplifying risks over time (Centeno et al., 2015; Hochrainer-Stigler et al., 2023; Li et al., 2021). This suggests a new dynamics of global climate risks, punctuated by social tipping points, with implications for broader-scale risk and discontinuities in social systems and behaviour.

Finally, there are temporalities of exposure and vulnerability to social risks themselves. Climate justice researchers have long explained the deeply patterned nature of vulnerability to climate—influenced risks (Boyd et al., 2021). These patterns of inequality are historically-rooted in social relationships and institutions (Berkhout et al., 2024; Mahanty et al., 2023). The deeper history of structured social and political processes shape both vulnerabilities and the capacity (or incapacity) to adapt. Time and temporality therefore act in complex ways to condition adaptation to climate change-influenced risks, and the capacities, constraints and limits which configure adaptive behaviour.

Normal climate, climate variability, climate change and social expectations

A confounding feature of climate change as a wicked problem is the problem of time. Weather and climate are intrinsically variable, at any given moment, across a day, between the seasons and from year to year, and of course across space. Our understanding of what is a 'normal' climate, from both a scientific and a cultural perspective, reaches back over deep time. Paleoclimatic records used to confirm the range of expected variability of climates go back up to 2 million years (Intergovernmental Panel On Climate Change (IPCC), 2023; Snyder, 2016). In the modern period, the primary index of climate change – global mean near-surface air temperature rise – is based on a pre-industrial baseline (1850-1900). This baseline is often used to establish a 'climate normal', although there have been iterations of the baseline, with global climate records for 1991-2000 now used as the baseline for reports by the World Meteorological Organisation and the Copernicus Climate Change Service.[1] Likewise, in making projections about future climate change, global circulation and related models reach into the far future (decades and centuries) to make projections about rates and scales of change of a wide range of climatic parameters (Stokes et al., 2022). Global climate models project anomalies from historically calibrated normal climates based on an understanding of biogeochemical and physical systems, including their dynamics over short and longer periods of time, now augmented by machine-learning techniques (Kochkov et al., 2024). For instance, the residence time of different gases in the atmosphere plays an important role in projecting radiative balances and anthropogenic forcings (Lynch et al., 2020).

For social actors, perception, experience and anticipation of weather and climate, and of climatic changes, is a complex overlaying of knowledge, practice, culture and memory (Adamson et al., 2018; Gregersen et al., 2023; Ji & Cobourn, 2021; Taylor et al., 2019). The everyday experience of time is

[1] https://climate.copernicus.eu/new-decade-brings-reference-period-change-climate-data

bound up in shared social experiences of weather and climate. To make sense of the passing of time and to anticipate futures, actors acquire, learn and reproduce a sense of the register of weather and climate (Harley, 2018). Weather and climates are culturally emblematic and generative of important social practices. Practical arrangements are made to anticipate and prepare for weather variability in all social contexts, from bringing an umbrella to building irrigation canals. This structures and reproduces cultural practices, identities (Butts & Adams, 2020) and expectations about how the future will unfold (Ensel, 2019). The everyday consumption of weather forecasting is one example (Böcker et al., 2013; Poudel et al., 2022; Radeny et al., 2019), an abstracted version of which are the projections designed using climate models. One of the reasons that making sense of climate change is so variable, fragile and problematic and why responses to climate change are often so ambivalent, is that they are often rooted in personal and cultural registers of time (Hulme, 2013).

Expectations, rational or otherwise, are a feature of all social life. Simple decisions, such as going to school or buying something, are always circumscribed by expectations about the future. Going to school makes sense as an acceptable social practice, but also as an investment in capacities that will be useful in future life. Making a purchase generally includes the expectation of future income to support a stream of future purchases. But future time does not have the same value as present time, an insight that is key to the idea of discounting (Lind et al., 2011). There are several reasons why future time may be less valuable than the present: we live in a present and prefer consumption and security now; we may no longer exist at some future point; we may be richer in the future; and other options may become available to us through personal, social, economic or technological change. The further out into future time our expectations reach, the greater the uncertainty with which we can attach probabilities to given outcomes (Knightian uncertainty, (Sunstein, 2023)), or even make a projection about possibilities (ignorance). Much about the future is simply an unknown. So near-term outcomes will generally have a greater value than those in the far-term.[2] In social science and economics there are fundamental disputes about the degree to which expectations by individuals, organisations and institutions can be seen as rational, or are better thought of as rules-of-thumb; heuristics that allow people to make judgements based on experience and well-founded biases to make choices and decisions. These disputes inevitably also colour the way we treat time and temporalities and their effects on social choice and decisions, including those related to social choices that we interpret as representing limits to adaptation.

A simple illustration of this point is the idea of a return period for a flood as it affects vulnerable households or farmers. Return periods may be both experienced and narrated as repeated floods, while also expressed as a probability calculated in flood risk models (Bates et al., 2023). A well-informed householder will have both cultural knowledge and experience of floods and an awareness of the

[2] Time preference is culturally specific. Australian Aboriginal cultures, for instance, have a concept of 'deep time' which values long continuities in their own right (Netana-Glover, 2023).

modelling projections about the likelihood of another. There may be social rituals around this awareness, such as the need to prepare for flood events as a condition of flood insurance. Flooding is likely to generate some damage and loss, whether economic, or as a sense of estrangement from a previously safe place (Tschakert et al., 2017). The householder may choose to accept these losses, or build resilience to flood risk, such as building flood walls (Choi et al., 2024; Gomez-Cunya et al., 2024; Hossain et al., 2022). One interpretation of this adaptive response is that it aims to maintain risks at a tolerable level. If return periods of flood change – that is, floods become more frequent – this changing temporality may affect attitudes to further adaptation investments, whether incremental or more transformative. The householder will make a judgement about the scale of losses implied and whether these are tolerable. Such judgements are rarely simple or personal, circumscribed by psychological, cultural, ethical concerns, as well as historical, economic and cultural contexts.

Temporal dynamics of adaptation constraints and limits

Perceptions of climate variability and expectations of future variability and change shape adaptation limits, as experienced by social actors. Expected resilience to climate risks, whether of a householder, a farmer or a water manager, assume an expected range of future climate states, informed by historical experience, lay and expert knowledge and projections, including uncertainties. This will also include an expectation of losses because of extreme weather events, and more or less well-developed plans to cope with these. For instance, pastoralists in Sahelian Africa have well-established portfolios of coping strategies for periods of drought (Nkonya et al., 2023; Tofu et al., 2023). Considering a definition of adaptation limits as a discontinuous shift in behaviour once adaptive effort has proven inadequate to sustaining valued objectives, expectations of the future, both in terms of risks and adaptive capacity and resilience, are clearly central. Even where actors expect higher climate-related risks, if they also believe they will have higher capacities for resilience, or the alternatives are worse, then the justification for behavioural change may be weaker (Adger et al., 2021). In the long debate about the role of mobility as a response to climate change, more recent attention has been paid to the role of immobility, voluntary or enforced (Cundill et al., 2021; Upadhyay et al., 2024; Yee et al., 2022). The emergence of adaptation limits are the outcome of historical processes, including the path dependency of institutional, cultural and political processes (Barnett et al., 2015).

Extreme events

While changes in average climate have been important to shaping political objectives related to climate change – such as the 1.5-2.0°C objective in the 2015 Paris Agreement – extreme events (heat waves, droughts, floods and storms) are arguably a more significant influence on private and public attitudes and behaviour. Here too there appears to be an effect of time, with initial salience and willingness to act fading quite quickly with time and distance (Arias & Blair, 2024; Hoffmann et al., 2022; Visconti & Young, 2024). In general, the adaptedness of an household or organisation and its vulnerability to loss will be shaped by the vulnerability of its most critical features to extreme events (Hewer & Gough, 2021). For a vineyard owner this could be reduced vulnerability to late frosts but also higher temperatures and increased risks of drought (Gannon et al., 2023). Adaptations for these risks, including the capacity to cope with periodic financial losses due to poor harvests, are part of a portfolio of options and strategies available to winemakers (Naulleau et al., 2021). The responsiveness of these adaptation options is tuned to the varying temporal characteristics of risks. For instance, while mitigation options against frost damage to vines need to be on a diurnal timescale, risk mitigation to drought can be implemented over a period of weeks and months. Expectations about vulnerability and resilience follow related temporal patterns. Changing periodicities for the onset of risks would alter these expectations, introducing new uncertainties. Social limits to adaptation are therefore framed by the layered and compounding temporality of climate-related risks, and the capacity of households and organisations to respond to them over the short- and longer term. The responsiveness of adaptation options to risks will influence whether valued objectives – making a profit, sustaining a livelihood, continuing a tradition – can be safeguarded and reproduced.

Changing frequencies and magnitudes of extreme events

The modelling of extreme events, in the present day and in the future, is hampered both by uncertainty related to their physical basis, as well as the compound nature of risk scenarios (Thornton et al., 2014). For instance, the assessment of the risk that a sea dyke is overtopped is related to projections of sea-level rise, as well as analysis of storms, storm tracks and associated storm surges across particular estuaries and coastlines. Actual loss-generating events will be the outcome of a combination of circumstances, natural and social, for which it is difficult to develop scenarios (Berkhout et al., 2013). Even high-resolution earth system models used for making climate projections find it hard to handle these specificities, with projections of heat being the best resolved (Harrington et al., 2021). In making judgements about whether risks are likely to become intolerable (the frequency of serious flood damage to property, for instance), the primary challenge faced by households and organisations will be to make sense of the likelihood of low probability-high impact events, the capacity to build resilience to them and the losses that may be caused. Key to these judgements will be attitudes and trade-offs between the intersecting temporalities of these factors. For instance, a decision to invest in private flood protection measures will be shaped by a perception of the risk of flooding, the affordability of measures (Rehan et al., 2024), the likelihood of public flood protection investments and an assessment of the avoided losses over time (Griggs & Reguero, 2021).

At a more aggregate scale, significant advances have been made in applying global climate models to making probabilistic assessments of climate extremes and to beginning to set these within a broader social, economic and cultural understanding of adaptation limits (Edwards et al., 2021; Tebaldi et al., 2021). Horton and colleagues provide projections at the global scale related to sea level rise and extreme heat (persistent external wet bulb temperatures above 33°C) under a high climate change scenario (RCP8.5) by 2100 (Horton et al., 2021). With greater warming, more places around the world will experience a wider range of climate extremes that lie outside conditions for which historical resilience has been built-up.

Figure 1 about here

Changing frequencies and magnitudes of extreme events generate a demand for greater adaptive effort by households and organisations. Currently well-protected coastal regions will become harder to defend, even with growing economic wealth and a willingness to invest in adaptive effort (Mach & Siders, 2021). Increasingly more resource-intensive approaches are likely to be deployed to address growing physical risks, a process that is captured in the idea of adaptation pathways (Haasnoot et al., 2020b). Risk and adaptation thresholds are met once a given option is no longer effective, leading to its potential substitution by another, often more resource-intensive and complex adaptive response (Toimil et al., 2021). The sequencing through time of options will differ between physical, socio-economic and cultural contexts. Each step reflects a 'soft limit' to adaptation, as existing approaches to resilience are replaced by new approaches (Piggott-McKellar et al., 2021). Hard adaptation limits reflect a situation where no viable adaptation options to building resilience exist and more transformative alternatives are considered. This process of adaptation is not binary, but a process of relational and context-specific adjustments. For instance, the notion of 'climate mobilities' views mobility and immobility that may be influenced by climate-related risks drawing on a multiplicity of other explanations of mobility, each with their own histories, not as exceptional and distinct cases (Boas et al., 2022, 2024). Hard limits may have a tangible and physical aspect, but they are always an outcome of historically rooted social and cultural processes.

Figure 2 about here

All adaptation implies the acceptance of some level of residual losses (Iizumi et al., 2020). In the trade-off between the costs of adaptation and the stream of future benefits which may arise from adaptation, some risk of loss remains. Growing risks imply growing residual losses, so that with growing frequencies or changing intensity of events, expected losses would be expected to grow, testing the viability of livelihoods and locations, even after adaptation.

Future availability of adaptation options and pathways

Just as climate risks change over future time, so the availability of adaptation options to social actors and organisations will change. This may be due to a growth effect (overall economic welfare grows, meaning that adaptation options become more affordable), a changing balance between costs and benefits (as climate risks grow, options which previously were not justified come to be seen as a good return on investment), falling costs of adaptation (for instance through increasing scale of adoption), or due to the technical or social innovation of novel options. For instance, early warning systems for heat waves may be made broadly available, allowing vulnerable groups to take simple and effective protective measures (Issa et al., 2021). Predicting how these effects will influence access to adaptation options by households and organisations, and whether the availability of options leads to their adoption, is complex (Noll et al., 2022). But in general, we would expect a wider range of adaptations to become available over time, even if these are unequally accessible and affordable.

Public policy and community and corporate action is likely to play an important role – in making new options available through investments in research and innovation, through providing incentives for adoption of adaptation options and practices, by providing compensation to losses (linked to arguments about loss, damage and liability), or through the mandating adoption of adaptation options (the requirement by lenders to have flood insurance in flood risk areas, for instance). The general point is that the capacity to adapt will change through time, with a changing portfolio of adaptation options and strategies available to a given social actor, group or place. As any actor approaches an adaptation limit, this awareness of new and changing ways of achieving resilience will inform their choices and decisions. In this sense, adaptation limits continue to be dynamic through time until they are actualised through discontinuous behaviours, such as a change in livelihood strategy. Ojea and colleagues (Ojea et al., 2020) analyse fisheries as socio-ecological systems (SES) which undergo adjustments in response to ecological changes in fish stocks as a result of climate and other changes (range contraction, habitat fragmentation etc). This generates responses in fisheries including catch decreases, new target species and fisheries conflicts, which in turn ramify into wider economic and societal effects, each with feedbacks across the SES (such as over-fishing which may lead to stock collapse and fleet relocation). For individual fishers a range of adaptive responses will be available through time, evolving in effort and significance from coping to adapting and finally to transforming (shifting from artisanal to industrial fishing, or exiting the seafood sector altogether). A similar pattern of unfolding responses will be observable in most socio-ecological systems underpinning economic and social development.

Cascading and systemic risks

As the scope and intensity of climate change grows, climate risks are increasingly viewed as cascading, amplifying or dampening through global economic, political and cultural connections (Li et al., 2021). Lawrence and colleagues (J. Lawrence et al., 2020) argue that cascading risks can propagate through physical and social systems as an outcome of a range of climate-society interactions: slowly emerging impacts (such as sea level rise); widening climate variability; extreme events; combined impacts (such as interacting coastal and river flooding); and surprises (new forms of risk, such as megafires and their impacts on global household insurance markets, (Murphy, 2023)). Tracing these combinations of interactions through multi-level global systems has proven difficult. Hochrainer-Stigler and colleagues (Hochrainer-Stigler et al., 2023) argue that there continues to be an ‘operationalisation gap’ in relation to systemic risks because the pathways of global risk transmission (and dampening and amplifying processes) remain unclear until they are manifested. Temporality is a feature of systemic risk in that the scale of risk depends on the speed with which risks are propagated through markets, supply chains or social systems relative to the speed of response. Markets themselves will respond as they seek to reduce exposure to risks or price-in cascading risks. Without public intervention, the outcome will typically be the shifting of risks to the least powerful and most vulnerable. Adaptation limits, as experienced by people and communities within these systems, will be shaped by their capacity to handle risks and shocks propagated through interconnected global systems. More recently, the debates about systemic risks have become entangled with the notion of ‘polycrisis’ with its analysis of fast and slow shocks (M. Lawrence et al., 2024).

Historical production of climate risks and vulnerability

Objections to the idea of polycrisis mirror a broader critique about the structured nature of risk, vulnerability and, ultimately, also limits to adaptation. For scholars of neoliberalism, the basis for many phenomena described by the climate crisis are based in capitalist relations of production and consumption (Margulis et al., 2023; Saad-Filho & Feil, 2024). This analysis draws on temporalities of global social relations, including the historical evolution of capitalist accumulation and crisis and colonialisation. Similar attention to the *longue durée* of social and cultural relations that inform understandings of climate change and responses to it are found in scholarship about indigenous communities and knowledges (Jackson, 2023). These framings and assessments suggest that the fairer resolutions to the predicaments of climate change impacts and adaptation will come about only with a deep rearrangement of these social relations (Shi & Moser, 2021).

Final remarks

Adaptation to climate-related risks by any social actor is a process that unfolds through time. Judgements about changing risks, changing capacities to adapt and changing potential losses are made through the complex overlaying of practice, knowledge and social and cultural expectations. These each also evolve through time, often in response to events and new knowledge – a court decision may change the calculus of expectation and alter perceptions of what is a tolerable, rather than an intolerable risk. In developing a mature analytical apparatus for understanding limits to adaptation we need to apply insights from across the social sciences dealing with the expectations of people and organisations and how these influence choices about adaptation in the present.

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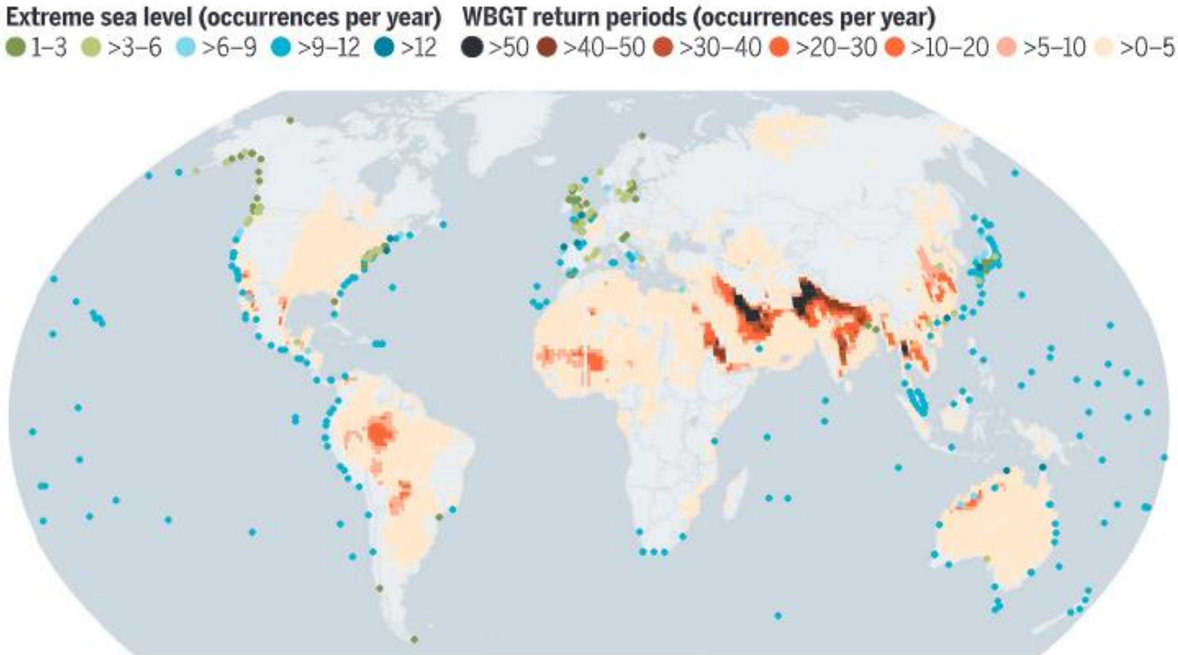
Figures

Figure 1

Frequent exceedance by 2100 of historically rare climate thresholds

Under the high-emissions scenario RCP8.5, at most coastal locations extreme sea level events historically defined as 1-in-100-year events are projected to range in frequency from once per year to more than 10 times per year due to the effects of sea level rise alone. Only point locations where historical event data are available are shown. Projected number of days per year by 2100 exceeding a 33°C wet bulb globe temperature (WBGT) in a high-emissions scenario are also depicted. Under standard assumptions of wind and solar radiation, a WBGT of 33°C corresponds to a wet bulb temperature of roughly 31.5°C. [Sea level data are from figure 4.12 in (*8*); WBGT data are from figure 3 in (*12*).]

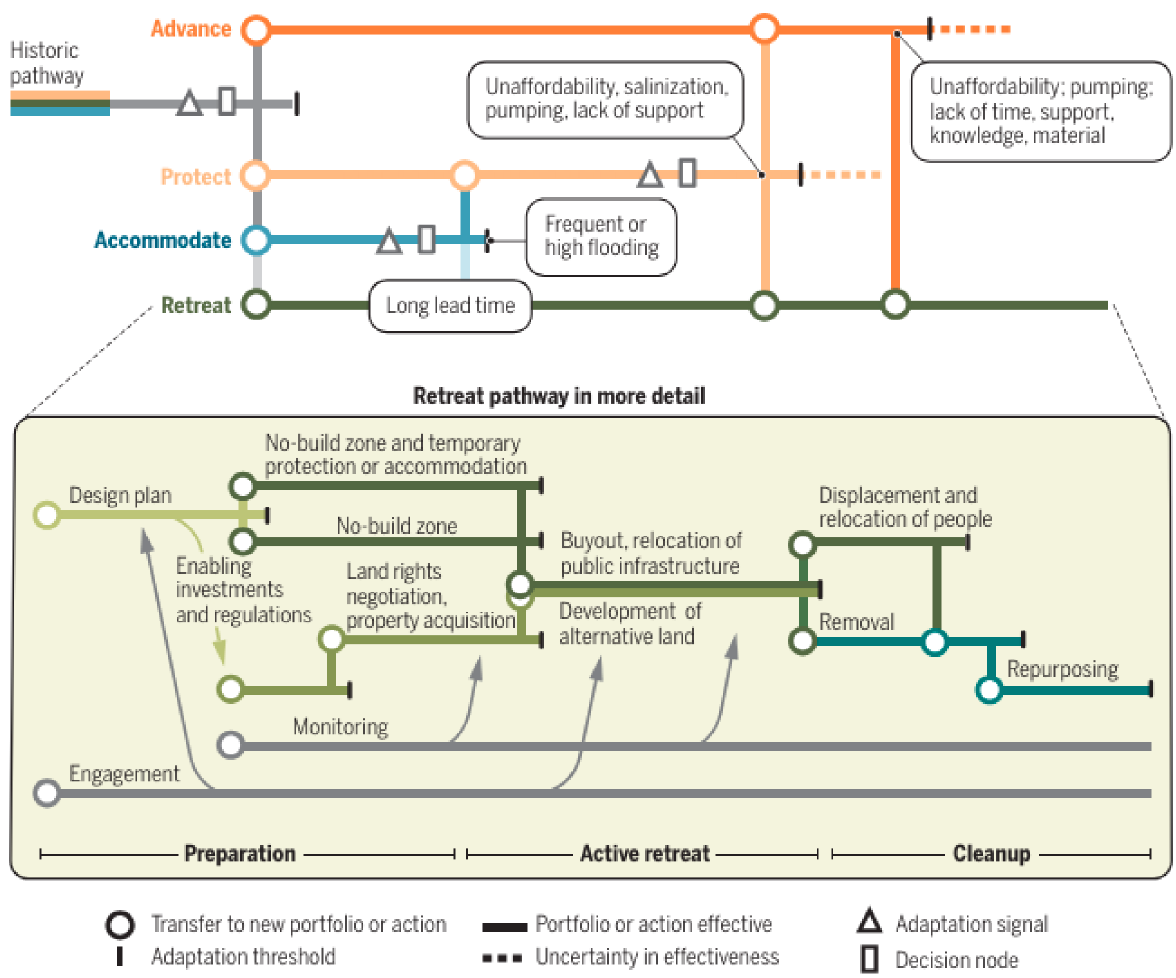


Source: Horton et al., 2021, *Science*, 327: 1279-1283.

Figure 2

Indicative adaptation pathways of retreat

Retreat is presented as a nested pathway within a broader pathways map, including advance, protect, and accommodate. Retreat comprises three stages: preparation, active retreat, and cleanup. Engagement and monitoring support planning and implementation (gray lines). After designing a plan, land use regulations and temporary measures can be implemented, followed by buyout. Enabling investments and regulations are precursor actions.



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