COMMENTARY:

Limits to adaptation

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An actor-centered, risk-based approach to defining limits to social adaptation provides a useful analytic framing for identifying and anticipating these limits and informing debates over society's responses to climate change.

An inadequate multilateral response on reductions in global greenhouse-gas emissions has resulted in much greater emphasis on adaptation to address the growing risks of climate change. Natural and social systems often have significant capacities to adapt, including the potential in social systems for transformative adaptation in response to climate-related risks[1]. Global-scale assessments of vulnerability to climate change have identified 'key vulnerabilities'[2] and 'tipping points'[3] suggesting thresholds in biophysical systems that, if exceeded, would pose major threats to sustainability and human welfare, and are thus 'reasons for concern'[4]. However, it is difficult to establish how the rate and magnitude of climate change and biophysical thresholds might relate to the capacity to adapt in social systems. Some adaptation limits have been clearly identified, primarily for ecological systems, exemplified by species extinctions. But little is known about limits in social systems — whether there are social limits to adaptation[5], what influences their likelihood, where these might lie, who they would affect and what the consequences of reaching such limits might be.

Many communities in highly-vulnerable regions like the Arctic are already facing limits in their capacity to adapt.

The existence of adaptation limits has broad implications. If the capacity to adapt is unlimited, a key rationale for reducing emissions of greenhouse gases is weakened and replaced by considerations of adaptation costs and benefits, and of equity concerns. However, research suggests that opportunities and resources to adapt may be finite for many social actors, whether these are individual households, businesses or governments[6]. Breaching adaptation limits will result in escalating losses or require transformational change. Hence, there is an urgent need to identify and predict where limits are likely to occur in order to assess and prepare for the potential consequences. Here we propose a risk-based approach to defining adaptation limits, provide two examples, and raise some implications and research needs highlighted by this perspective.

The utility of the current literature on adaptation limits is weakened by ambiguity. Terms such as thresholds, limits, barriers and constraints are used interchangeably, yet their meanings differ. Although an adaptation barrier or constraint represents a stressor or an impediment to adaptation that can in principle be overcome[6], an adaptation limit implies a level of adaptive capacity, broadly defined, that cannot be surpassed. Providing a sound conceptual approach is a necessary first step to enable progress in building knowledge about limits. We believe an actor-centred approach to defining social adaptation limits will bring clarity, and can inform practical action.

Adaptation is primarily intended to reduce climate-related risks to things we value[7]. The concept of risk includes extra elements that are useful in developing a clear definition of adaptation limits; notably the consequences, likelihood and uncertainty of climate-related hazards[8]. Risk perceptions influence a homeowner's desire to live in a particular place, a forestry company's management strategy in the face of climate-related hazards or an insurance company's unwillingness to provide disaster coverage. Adaptation processes can be viewed as attempts to keep risks to valued objectives — such as a home by the beach or a profitable forestry business — at a tolerable level in the face of climate-related threats.

We recognize that actors, from individuals to corporations and governments, may differ in their perceptions, experiences and evaluations of risks and in their willingness to take actions to abate risks. For instance, farmers in the same region may differ in their perceptions of the magnitude, consequences or uncertainty of climate-related risks, in their tolerances of potential crop and related losses and in their willingness to shift to new crops or management practices. Governments may differ in their approach to crop insurance.

A risk-based approach to limits is scalable, broadly applicable and readily intuitive by a broad array of actors.

To simplify this complexity, Klinke and Renn have argued that actors will implicitly or explicitly place risks to their valued objectives into one of three categories involving different types of response[8,9]: acceptable risks are risks deemed so low that further efforts in risk reduction (adaptation) are not justified; tolerable risks relate to situations where adaptive, risk-reduction efforts are required for risks to be kept within reasonable levels[10]; and intolerable risks are those which fundamentally threaten a private or social norm — threatening, for instance, public safety, continuity of traditions, a legal standard or a social contract[11] — despite adaptive action having been taken. On reaching an intolerable risk level, we normally expect a discontinuity of behaviour in order to avoid the risk, whether this is a homeowner's decision to move, or a forester selling off land, as the alternative is increasing losses. The question of what is acceptable, tolerable or intolerable remains with the individual actors, as they shape collective responses.

Figure 1 depicts these risk types, focusing on the relationship between the frequency and intensity of adverse impacts. According to this representation, adaptation occurs within the zone defined

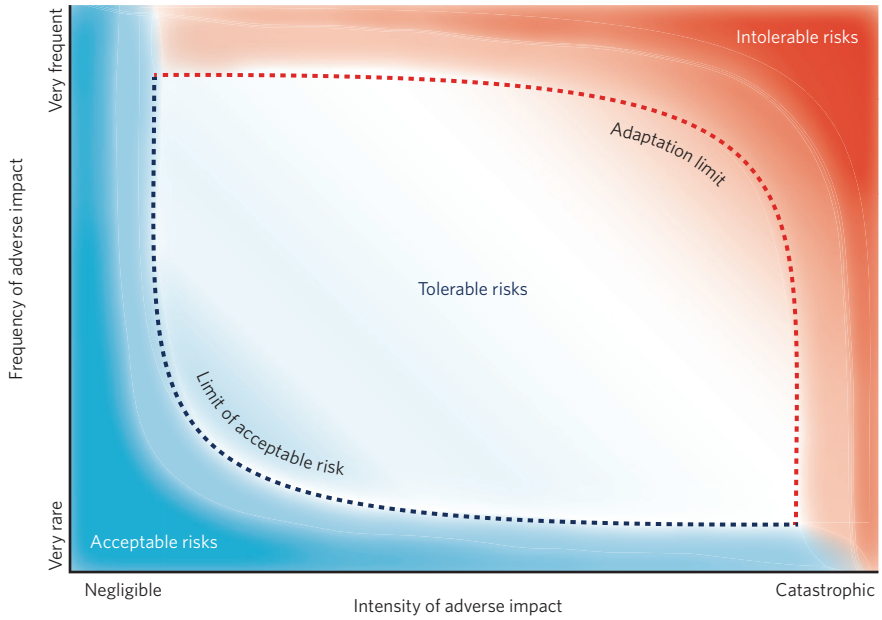

Figure 1 | Acceptable, tolerable and intolerable risks in relation to adaptation limits. Figure drawn by Yuka Estrada, IPCC, based on ref. 8.

as representing a tolerable risk. For instance, a farmer seeking to cultivate a specific crop under increasingly stressed water resources will invest in available adaptation options to raise the efficiency of water use, increasing adaptive effort as access to water resources becomes more constrained. At some point, adaptation effort under the existing regime will become disproportionate to the benefits and a new adaptation action, such as irrigation, is needed to maintain a farming livelihood. This new adaptation would allow farming or other valued objectives to continue. But, at some point, no new adaptation options are available to respond to growing risks, or the level of adaptive effort required to maintain valued objectives becomes infeasible. At this point the farmer may, for example, choose to abandon farming altogether.

The blurred boundaries between the zones of risk seen as acceptable, tolerable and intolerable signify the diversity among actors and the potential for debate over the level and distribution of risk. In the absence of new adaptation options or resources, the threshold for intolerable risks represents a point at which an actor must either live with the risk of escalating loss and damage[12], or transform behaviour to avoid the risk[1]. Such a discontinuity in risk or behaviour is symptomatic of an adaptation limit being reached.

We therefore propose a definition of an adaptation limit as a point at which an actor can no longer secure valued objectives from intolerable risk through adaptive action.

Two rather different examples illustrate the definition. First, we take rice cultivation in South Asia. Rice pollination and flowering has a threshold temperature of 26 °C (at night), with a 10% decline in yield for every 1 °C increase in temperature above that[13]. In this example, the adaptation limit is established by the inability to breed rice varieties that pollinate with night-time temperatures above the 32–35 °C range[14]. The valued objective is to produce rice as a staple crop and for export. The intolerable risk is a level of loss in rice production, farmer livelihoods, income from exports and food security. Rising temperatures increase the future probability that rice harvests may fail.

Such failures would probably impose economic losses on farmers, as well as generate broader economic and political impacts. If no affordable alternative supplies of rice can be found, it could entail excessive costs to consumers and/or changing dietary practices. The increasing threat of these impacts could lead farmers and policymakers to change long-established practices of rice cultivation and pursue security though alternative crops. For many reasons, change in response to limits can be a complex process. The tolerable degree of risk differs among actors and debate could slow collective adaptive action. The level of disruption caused by escalating losses and discontinuities at the limit boundary could potentially be mediated by designing effective adaptation processes for managing change associated with the limit. Better recognition of the limit could reduce losses during such a transition, whereas failing to address the risk as a limit is reached could result in catastrophic economic and social costs.

Our second example is at the societal level, and concerns a risk to cultural continuity[7]. In the mid- to late fifteenth century, after about 400 years of settlement, the complex and vibrant Norse Greenland society came to an end. This is often seen as a failure to adapt to climatic changes in the 'Little Ice Age'. In fact, the story of this collapse represents an example of limits to adaptation. Norse Greenlanders adapted in a variety of ways by shifting to new ways of exploiting marine mammals as harsh climatic conditions forced declines in agriculture and domestic livestock production[15]. But faced with growing competition from Inuit hunters, declining trade in ivory and fur with Norway, and a worsening climate, these adaptations were insufficient to maintain risks to community continuity at tolerable levels.

We believe an approach to defining adaptation limits linked to the (in) tolerability of risks is useful because it engages with the social, institutional and cultural contexts shaping adaptation and risk. It also incorporates the role of social, economic and cultural values in defining adaptation limits[5,7]. By starting from the perspective of social actors, this approach recognizes that adaptation limits always need to be defined from the perspective of a specific actor facing the loss, be that an individual, community or region. This also applies to global-scale biophysical changes articulated in the key vulnerabilities[2] described by the Intergovernmental Panel on Climate Change . Identifying 'dangerous climate change' relies on understanding which actors will be affected and whether they are facing adaptation limits. As the rice and Norse cases show, a risk-based approach to limits is scalable, broadly applicable and readily intuitive by a broad array of actors. Focusing on the potential intersection of intolerable risks and valued objectives directs our attention beyond the biophysical impacts to identifying the broader social dimensions of potential losses. This will be part of accounting for, debating over and allocating resources at adaptation limits.

Given the difficulties in determining limits to adaptation, there is an urgent need for research in key domains — including agriculture, water resources management and disease control — to determine where limits may exist so that actors may anticipate and plan to mediate the hardships that cannot be avoided. The capacities to provide early warnings and to operate

across scales are two important features of such efforts. Beyond these, a concern for adaptation limits draws attention to the design, capabilities and trust in institutions needed to implement risk management *in extremis*. Many communities in highly vulnerable regions — such as the Arctic — are already facing limits in their capacity to adapt, and losses that are difficult to compensate for. As climate change accelerates, increasingly more communities, regions and sectors will begin to approach these limits. We need to be aware of this gathering storm of crises, the potential for changes in risk and behaviour at limits and the likelihood that those changes will generate challenging debates. Researchers need to begin making progress in predicting and anticipating adaptation limits, and policymakers need to start making plans for managing the consequences of exceeding adaptation limits. ❐

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References

1. Kates, R. W., Travis, W. R. & Wilbanks, T. J. *Proc. Natl Acad.Sci. USA* **109,** 7156–7161 (2012).
2. Schneider, S. H. *et al.* in *IPCC Climate Change 2007: Impacts, Adaptation and Vulnerability* (eds Parry, M. L., Canziani, O. F., Palutikof J. P., van der Linden, P. J. & Hanson, C. E.) 779–810 (Cambridge Univ. Press, 2007).
3. Lenton, T. *et al. Proc. Natl Acad. Sci. USA* **105,** 1786–1793 (2008).
4. Smith, J. B. *et al. Proc. Natl Acad. Sci. USA* **106,** 4133–4137 (2009).
5. Adger, W. N. *et al. Climatic Change* **93,** 335–354 (2009).
6. Moser, S. C. & Ekstrom, J. A. *Proc. Natl Acad. Sci. USA* **107,** 22026–22031 (2010).
7. Adger, W. N., Barnett, J., Brown, K., Marshall, N. & O'Brien, K. *Nature Clim. Change* **3,** 112–117 (2012).
8. Klinke, A. & Renn, O. *Risk Anal.* **22,** 1071–1094 (2002).
9. Renn, O. *Risk Governance: Coping with Uncertainty in a Complex World* (Earthscan, 2008).
10. Hall, J. W., Brown, S., Nicholls, R. J., Pidgeon, N. F. & Watson, R. T. *Nature Clim. Change* **2,** 833–834 (2012).
11. Adger, W. N., Quinn, T., Lorenzoni, I., Murphy, C. & Sweeney, J. *Nature Clim. Change* **3,** 330–333 (2013).
12. Verheyen, R. & Roderick, P. *Beyond Adaptation: The Legal Duty to Pay Compensation for Climate Change Damage* (WWF-UK, 2008).
13. Peng, S. *et al. Proc. Natl Acad. Sci. USA* **101,** 9971–9975 (2004).
14. IPCC *Climate Change 2001: Synthesis Report* (eds Watson, R. T. *et al.*) (Cambridge Univ. Press, 2001).
15. Dugmore, A. J. *et al.* in *Adapting to Climate Change: Thresholds, Values, Governance* (eds Adger, W. N., Lorenzoni, I. & O'Brien, K. L.) 96–113 (Cambridge Univ. Press, 2009).

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