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Little floods everywhere: what will climate change mean for you?

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Abstract
The consequences of climate change are often conceptualised in terms of the changing risks of natural disasters, or as reductions in future economic output. When understood in these terms, it is all too easy to believe that one might "get lucky"—that the floods won't affect those of us who don't live by the waterfront, and that the heatwaves won't affect the salaries or job security of those of us who go to work in air conditioned offices. The consequences of climate change, serious though they may be, seem far away. Contrary to this perspective, we argue that changing risk profiles, even marginal or distant changes, are likely to strain the underlying fabric of societies, and thus have profound consequences for everyone. Even for individuals who are relatively insulated from the direct physical consequences of climate change, it may well be that there is little chance of "getting lucky." This has important implications for how we perceive and assess the benefits of climate action. We therefore call for greater efforts to understand the system-wide social consequences of increasing disaster risks.

Keywords Climate change damage · Natural disaster risk · System-wide social costs

1 Introduction

There are significant efforts to describe the types of physical changes that we might expect as a consequence of climate change at national and regional scales (Ranasinghe et al. 2021; Gutiérrez et al. 2021; USGCRP 2017). Climate information services (Bruno Soares and

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Buontempo 2019) and academic studies provide information about variables such as the change in seasonal average and seasonal extreme temperatures and rainfall. These are often provided at local scales (Lowe et al. 2018; National Centre for Climate Services NCCS 2024; vanden Hurk et al. 2014) to support adaptation activities, and have been extended into quantification of the changing risk of flood, droughts, heatwaves, wildfires, etc. (USGCRP 2017; Hannaford et al. 2022), as well as the economic evaluation of those risks (Willner et al. 2018; Naumann et al. 2021; García-León et al. 2021; Smith et al. 2021; Wang et al. 2021; Hsiang et al. 2017). This information is important in facilitating planning at national and regional levels, but it does not fully capture how climate change will test and strain social and political institutions.

The cost of climate change is likely to exceed the sum of its parts. Projections of changes in local climate, whether they are reliable or not (Stainforth and Calel 2020; Stainforth et al. 2007), do give a sense of physical risks and their direct economic costs, but these costs are usually understood within a context of relatively unchanging social and governance structures. The system-wide social consequences could be quite different if changing physical risks and compound events undermine these structures.

2 Changing disaster risk

Let us start by taking a conventional approach to assessing the cost of floods. Consider the anticipated increase in the risk of river and surface flooding in Central and North West Europe (Kundzewicz et al. 2017; Else 2021). If you are hit by such floods it may be catastrophic on a personal level, but insurance and government support may be available to rebuild damaged properties, roads, and civic amenities. Government support may also be available to build flood defences to prevent future floods. Increased risk of flooding may be personally costly, and at times even personally devastating, but may nevertheless be something our societies simply choose to live with. The choice is a matter of balancing the expected losses against the cost of additional protective measures.

An important element of climate change, though, is the changing risk of having to deal with multiple disasters in parallel, or in quick succession (O'Neill et al. 2022; New et al. 2022). Whether or not the events are physically connected or correlated (Seneviratne et al. 2021), when the flood risk increases across a region, it becomes *much* more likely that many locations will be hit, even though any particular location may still be unlikely to get hit. Climate change should not be understood just as the increased risk of this or that location experiencing a catastrophic flood—although it does entail that, of course. Rather the essence of climate change is that it will force us to confront "little" floods all over the place, sometimes all at once. By "little" we mean only that the floods aren't large enough individually to affect the workings of society on a national or regional scale. Many of these "little floods" could nevertheless be extremely large in a conventional sense.

A simple numerical example may help to make this point more concrete. Suppose the chance of flooding in a particular year and locality goes up from 0.1% to 0.2%. Although the risk of what today would be considered a 1,000-year-flood doubles, it may still seem like a remote risk to anyone living there. Now consider if there are 100 such communities. The probability that at least one of them floods in a given year also nearly doubles, from 9.5%

to 18.1%.[1] That may not seem like a step-change numerically, but at that rate, we'd now expect to see such a flood in practically every election cycle. Moreover, the chance that two or more communities are flooded in the same year nearly quadruples, from 0.46% to 1.74% (if the events are independent).[2] That means you'd expect to be hit by multiple 1,000-year-floods in the same year, roughly once every 50 years instead of once every 200 years. The chance of three or more floods increases by a factor of 7, the chance of four or more floods increases by a factor of 15, and so on. If you have a stroke of bad luck, you might get these flood years in rapid succession, instead of evenly spaced across the centuries. That means you'd need capacity to respond to these kinds of scenarios in consecutive years, before you have time to rebuild your reserves.

This is a mere toy example, meant to illustrate how small changes in the risk of individual events can compound in counter-intuitive ways. As a practical matter, our example likely understates the scale of the challenge—if floods come in clusters, the risk of parallel flood events will increase even more dramatically than our simple calculations suggest. Indeed, precisely this kind of compounding risk is found in more complex models. For instance, Bevacqua et al. (2021) shows that a 4% increase in the intensity of precipitation can lead to a 93% increase in the spatial extent of extreme precipitation. In a similar vein, Bevacqua et al. (2019) projects that the fraction of European coastlines experiencing frequent compound flood events will nearly quadruple by the end of the 21st century.

3 System-wide social consequences

Once we acknowledge that the risk of disasters is likely to change, it is incumbent upon us to reflect on whether there is anything special about these changes, over and above their direct impact (Newman and Noy 2023). The important thing to grasp about the possibility of multiple communities being hit by 1,000-year-floods in rapid succession is that the cost of this kind of flooding will go far beyond the localised rebuilding of properties, installation of flood defences, and redesign of drainage systems. Increasingly, the consequences will be felt across the whole of society, even among those who are relatively insulated from the flooding itself. The increased risk raises the cost of insurance as well as the taxpayer's bill to support the affected communities, it cannibalises spending from other public services like healthcare and education, and makes people more likely to leave their homes in search of better prospects in other communities. It is easy to see how little floods everywhere could end up putting a far greater strain on social and political institutions than do isolated catastrophes.

Climate change is not just a story of floods, of course. The combination of increased flood risk and increased risk of high temperatures and drought will expose vulnerabilities in electricity supply and transmission infrastructure, road and rail systems, healthcare sys-

[1] These probabilities follow from a simple binomial calculation. If the probability that each of 100 independent communities is hit by a certain type of flood event in a given year is 0.1%, the probability that at least one is hit within that time frame is $1 - 0.999^{100} = 0.095$. If events are dependent (e.g. floods come in clusters or not at all), this does not affect the probability of at least one flood.

[2] Again, this is based on a simple binomial calculation. The probability of two or more communities being flooded is $1 - 0.999^{100} - \binom{100}{1} 0.001^{1} \times 0.999^{99} = 0.0046$, and 0.0174 when the probability of an individual flood is 0.2%. If events are positively correlated (i.e. floods come in clusters or not at all), the probability of two or more flood events would more-than-quadruple.

tems, and more besides. Any one event may not be catastrophic for a whole country, but if different aspects of the system are being hit by more and more crippling events, in diverse locations, with increasing frequency, then our ability to respond will diminish and the costs to society could grow substantially.

Evaluating the consequences of climate change therefore isn't simply a matter of estimating the change in risk, multiplying it by the cost of a typical event, and adding them up. This approach is analytically appealing, but fails to consider the damage that climate change may do to the very social structures that underpin the costings of individual floods (markets, trust, rule of law, etc.) (Sen 1999; Olsson 2016). Social structures built to absorb isolated shocks may crumble under the pressure of frequent natural disasters. Though it would be incredibly costly to rebuild them, these costs are nowhere to be found in conventional estimates of climate damages.

History offers many examples of societies that have collapsed under the weight of repeated and prolonged environmental stresses (Homer-Dixon 1994; Diamond 2005; Zhang et al. 2006; Tol and Wagner 2010; Kennett et al. 2012). In modern times, recurrent droughts have been implicated in Sudan's and Syria's descents into civil war (De Juan 2015; Kelley et al. 2015). It is obviously challenging to parse out the contribution of environmental stress on societal collapse (Burke et al. 2009, 2010; Buhaug 2010; Theisen et al. 2012, 2013; Hsiang et al. 2013; Buhaug et al. 2014; Raleigh et al. 2015; Schleussner et al. 2016; Koubi 2019), and there is always disagreement about its role in any particular conflict (Kevane and Gray 2008; Selby et al. 2017; Kelley et al. 2017; Benjaminsen et al. 2012). Nevertheless, it is clear that we should not assume climate change poses zero risk to social and political stability.

For those living in high-income countries, it might be tempting to believe that the compounding nature of the costs will most affect developing countries with more vulnerable institutions and infrastructure, but it is also possible that the opposite is true. More developed nations have a lot more legacy infrastructure, which is perceived to be reasonably robust, and around which the whole of society is built. It may be particularly devastating if those structures are increasingly shown to be unhelpfully optimised to past climatic conditions (Larsen et al. 2008).

These consequences will not be confined to any one nation or region, but will ripple across our globalised society. The impact of the war in the Ukraine on wheat markets has highlighted the vulnerability of the global system to supply disruptions (Devadoss and Ridley 2024). There are many such examples in global supply chains, ranging from computer hard disks (Ye and Abe 2012) to mineral suppliers (Coulomb et al. 2015) to sunflower oil (Wood 2022; National Sunflower Foundation 2024). Climate change amplifies this threat. Changing disaster risks make it plausible that, over the space of a handful of years, many different locations associated with a particular product will be hit by the physical consequences of climate change. This could lead to global supply chain disruptions even for products made by many diversely located suppliers. The direct impacts on supply would increase the prices of the things we enjoy and the things we need to keep our societies functioning, including food and medicine. Greater volatility and uncertainty could further inflate prices. And on occasions when the shortage of an essential good becomes too severe, the cost is not simply a matter of higher prices—the human cost may quickly become unacceptable with consequences for social and political stability.

4 Discussion

What does this add up to for an individual in Sheffield, Boulder, Heidelberg, Cairns, Cape Town, Suzhou, or Bangalore? For those who experience a flood or heatwave or wildfire, the consequences may be devastating. But even the people who are relatively insulated from the direct physical consequences of climate change will, nevertheless, be profoundly affected. The reasons for concern, for many, are not primarily related to the physical risks they face personally, but to the larger social and political threats that those risks pose in the aggregate. Many small floods, droughts, wildfires, heat waves, windstorms, etc.—small in terms of their global impact—could be a substantial drain on our societies' resources. The result will be either substantially higher taxes or a diversion of funds from existing priorities, or both—a steady degradation of education and health services, and of infrastructure and institutions.

The erosion of the public goods that we have come to take for granted will affect everyone. It's not just the water or the fire we need to worry about, but whether your country will be able to maintain health, education, and transport systems that look anything like what exists at present. Climate change may force our societies to constantly fight to retain what we already have, rather than having capacity to build a better world for future generations. And that change in outlook, from a positive-sum world to a zero-sum world, is likely to have serious consequences for our politics, too (Rachman 2011; Davidai and Ongis 2019; Chinoy et al. 2023).

5 Conclusion

Climate change assessments need to reflect system-wide social consequences much better than they currently do. At present they typically focus on physical impacts, and on translating those impacts into economic losses under the assumption that something like our current social structures will persist. Even studies that explicitly incorporate climate-related mortality implicitly assume a high degree of social stability (Bressler 2021; Bressler et al. 2021). This kind of description of the future does not account for the possibility that a second and third year of drought eventually leads large numbers of young men to leave their farming communities for the cities (as they did in Syria), triggering political unrest that unleashes a civil war and a massive international refugee crisis (Kelley et al. 2015). Nor does it leave room to imagine that such a refugee crisis might create political polarization and backlash in destination countries (Hansen and Randeria 2016; Art 2018; Harteveld et al. 2018; Vasilakis 2018; Dinas et al. 2019; Emilsson 2020; Nicoli and Reinl 2020; van der Brug and Harteveld 2021; Cohen et al. 2022), even threatening their social stability (Lischer 2017; Torki et al. 2020).

We are calling for more research on the system-wide social consequences of changing disaster risk. We need new initiatives from those with the power to convene researchers across multiple relevant disciplines. Organisations such as national academies should create fora for geoscientists to engage with engineers and urban planners who study the resilience of our physical infrastructure, and with social scientists who study the resilience of social and governing institutions. The silos of academic research have left a significant gap in our understanding; major scientific bodies and funders should aim to direct more of the research community's collective attention towards filling this gap. Furthermore, it should be central to the IPCC's assessments to provide a better understanding of the nature of system-wide risk. The research community needs to urgently produce a robust body of evidence on this in time for inclusion in the seventh assessment report.

We believe that narrative approaches (Shepherd et al. 2018) are important to this effort. These kinds of events are sufficiently rare in the historical record that we cannot realistically validate the sort of complex socio-physical models that would be necessary to describe them. Reliance on formal models, in this context, is very likely to produce excessive precision and over-confidence. Narrative approaches, while rigorously grounded in our understanding of social and physical processes, put more emphasis on exploring the space of possible outcomes. They can help us better connect plausible descriptions of future physical changes (Dessai et al. 2018) with the impacts of climate change as they will be felt by many (Bhave et al. 2018; Hazeleger et al. 2015). Indeed, we have used a narrative approach here to shine a light on the under-appreciated damage that climate change may do to social and political stability, through small changes in average risk that lead to much more frequent disasters.

The public and our policy makers are in urgent need of a better picture of what climate change could mean for the integrated structure of our societies. For societies to be in a position to wrestle with the true benefits and costs of climate action, we need to make real the ways in which everyone is vulnerable to climate change, even those who are less exposed to direct physical risks.

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