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PERSPECTIVE

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Anthropocene risk

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The potential consequences of cross-scale systemic environmental risks with global effects are increasing. We argue that current descriptions of globally connected systemic risk poorly capture the role of human–environment interactions. This creates a bias towards solutions that ignore the new realities of the Anthropocene. We develop an integrated concept of what we denote Anthropocene risk—that is, risks that: emerge from human-driven processes; interact with global social–ecological connectivity; and exhibit complex, cross-scale relationships. To illustrate this, we use four cases: moisture recycling teleconnections, aquaculture and stranded assets, biome migration in the Sahel, and sea-level rise and megacities. We discuss the implications of Anthropocene risk across several research frontiers, particularly in the context of supranational power, environmental and social externalities and possible future Anthropocene risk governance. We conclude that decision makers must navigate this new epoch with new tools, and that Anthropocene risk contributes conceptual guidance towards a more sustainable and just future.

In recent decades it has become increasingly apparent that global phenomena, such as financial crashes and disease outbreaks, propagate more quickly than in the past and with greater geographic spread[1]. These episodic shocks are also occurring alongside ongoing protracted crises, which may morph into new forms, creating a sense of a never-ending crisis[2,3]. Prominent cases of interacting, systemic crises include the large-scale human migration from the Middle East into Europe[2], the ongoing Syrian conflict[3] and the financial crises of the 2000s that interacted with oil price fluctuations and commodity crises[3]. Such complex systemic phenomena have neither a clear cause nor simple blueprint solutions[4], owing to a combination of often-contested social, technological, ecological and geophysical drivers[3,5,6].

Various efforts to classify and organize these types of linked systemic phenomena have been made, including global systemic risks, nested vulnerabilities and globally networked risks[5]. In this Perspective, we argue that these dominant risk framings are inadequate for the task of dealing with the dawn of a geological epoch in which humans are a dominant force of change on our planet—the Anthropocene. As we elaborate below, the emerging geographical and temporal dynamics of this new proposed epoch, in combination with increased global connectivity through teleconnections and telecoupling dynamics[7], have profound implications for how global systemic risks are understood and eventually governed.

Here we take stock of existing dominant global risk frameworks, highlight their gaps from a social–ecological perspective and elaborate why a new concept of global environmental systemic risks is needed. We use four illustrative case studies to highlight key dimensions of these risks, and explore future research frontiers of interest to a wide research community encompassing climate, ecology, economy, technology and finance.

What are Anthropocene risks?

The notion of ‘systemic risks’ has gained considerable traction in both the scientific and policy communities over the past few years. Systemic risks have a number of different definitions, but are in general viewed as an emergent feature of complex systems in which risks result from poorly understood interactions within the system, when these interactions are more than the sum of their parts and therefore often emerge as surprises[8]. Current understanding of such systemic risks relies heavily on concepts of global networks[9] and complex adaptive systems[1].

The literature on global systemic risk has hitherto been dominated by the finance[1] and technology sectors. Prominent international policy arenas are increasingly exploring the evolution and implications of these risks. The Intergovernmental Panel on Climate Change (IPCC), for example, has made several, increasingly sophisticated efforts to capture complex risks, using interacting frameworks such as Reasons for Concern and Key Risks[10]. The World Economic Forum publishes an annual perception analysis of global risks and how they have changed through time[11], including some environmental risks (for example, water stress and extreme weather)[2].

Although all of these initiatives contribute in important ways to current understandings of global risks, none of them are able to fully capture the anatomy of risk and human–environmental processes that are shaping new systemic environmental risks. For example, although scholars have made considerable progress in understanding and modelling systemic risks in the financial system, only recently have we begun to understand possible systemic risks created by climate change and its impacts on ecosystems around the world[6]. Recent analyses from the World Economic Forum integrate environmental and climate dimensions in their global risk assessments (which are generated from survey data), but do not incorporate actual Earth-system data and modelling. The IPCC reports are without doubt the most authoritative summary of connected risks induced by climate change, yet there is an acknowledged need for improving the characterization of socioeconomic processes, as well as how complex adaptation to climate change might modulate cross-scale and cross-sectoral risks[10].

These dominant global systemic risk framings are often criticized for global geographic biases[12], failing to resolve small-scale system features (such as local feedbacks) and omitting consideration of power, equity, ethics and justice[3]. This is problematic, as addressing

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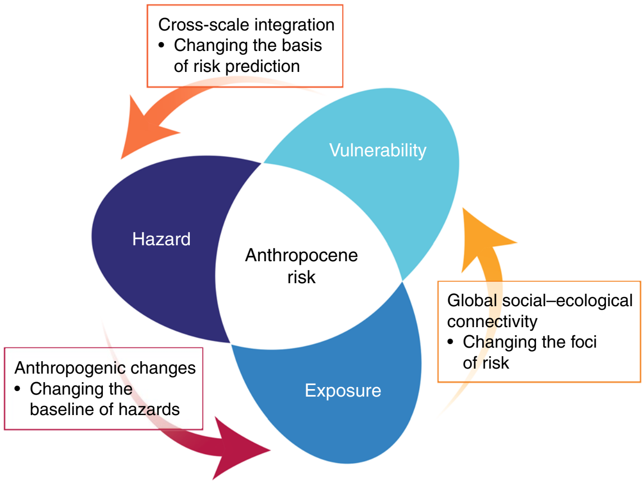

Fig. 1 | Conceptual diagram of how Anthropocene risk interacts with more traditional notions of risk. First, anthropogenic changes to the Earth system modify the baseline for hazard assessment. Second, global social–ecological connectivity modulates exposure and vulnerability, and thus the foci for risk management. Third, cross-scale integration can alter how and where risks are predicted and perceived.

the scale and magnitude of global environmental changes will require confronting the underlying reasons for the unequal distribution of power and wealth, and the coincident implications for the biosphere and Earth system[13,14]. Given these limitations, we introduce Anthropocene risks as a complementary approach to existing systemic risk frameworks (Fig. 1). We define Anthropocene risks as those that:

1. Originate from, or are related to, anthropogenic changes in key functions of the Earth system (such as climate change, biodiversity loss and land-use change)
2. Emerge due to the evolution of globally intertwined social–ecological systems, often characterized by inequality and injustice
3. Exhibit complex cross-scale interactions, ranging from local to global, and short-term to deep-time (millennia or longer), potentially involving Earth-system tipping elements

Anthropogenic changes. The Anthropocene is the proposed new geological epoch that posits that human activity is the prime driver of physical and biological changes in the Earth system[15]. Humanity now modifies weather patterns, climate, land surfaces, the cryosphere (the frozen parts of the Earth), the deep ocean and even evolutionary processes in ways that fundamentally alter life's interactions with its environment. Many of these systems have displayed accelerating rates of change since the 1850s[15], altering the basis of scientific risk prediction in unprecedented ways. Some regions and biophysical processes have been highlighted as 'sleeping giants'[15] with the latent potential to accelerate global change through various feedback dynamics. 'Planetary boundaries'[16] have been proposed in response to these 'tipping elements' or 'planetary-scale tipping points'[17], which entail both shorter-term and very-long-term temporal dynamics. Given the importance of the stability of Earth-system processes to the emergence and success of human civilization[18], these anthropogenic perturbations are central to our definition of Anthropocene risk. Likewise, we eschew notions of 'high probability/low risk versus low probability/high risk' in favour of a holistic, systems dynamics-oriented perspective.

Furthermore, the Anthropocene did not simply emerge from an undifferentiated humanity, but rather through a highly imbalanced world in which very few accumulated vast wealth via, ultimately, emitting vast amounts of fossil carbon. This disproportionate accumulation—in concert with the delayed effects of climate change, and the asymmetric impacts to those least responsible for climate change[19]—underpins the need to consider past, present and future distributions of power in the context of the Anthropocene.

Global social–ecological connectivity. Global connectivity can trace much of its current roots to the Columbian Exchange, which broadly highlights the extraction of natural resources (silver from South America to East Asia, potatoes from the Americas to Europe, for example) and the forced relocation of people across oceans (such as slaves from West Africa to the Americas)[20]. These extractive processes, by which the powerful world removed the human and natural wealth of the less powerful, set the stage for the contemporary configuration of power and distribution of wealth among nations. Equally important, modern corporate entities have their roots in this historical geopolitics of colonialism[12]. This reorganization of people and traded goods also initiated a widespread shuffling of cultural and biological diversity that continues to this day.

As such, social–ecological systems across geographies are more likely to be connected through global trade, international institutions, financialization and communication flows. Recent work has highlighted global 'tele-couplings': social processes that can drive system feedbacks despite being distant in space and time. For example, strong deforestation regulations lead to deforestation leakage in less-well-developed neighbours, international food trade drives distant groundwater depletion (often among poor, smallholder farmers)[21] and global trade leads to contagious exploitation of marine resources[21,22]. The profound global connectedness and power asymmetries in global social–ecological systems, accelerated by the Columbian Exchange, have ricocheted through to modern times. Figure 2 demonstrates not only the massive increase in palm-oil production, but also the countries that are driving this change. Many of the top importers of palm oil (although not all) are thus driving explosively exploitative environmental change in other, often marginalized or poor nations. Environmental injustice and inequality are embedded in the notion of Anthropocene risk, given that these risks are not simply about globalization, but undermine the very functioning of key biogeophysical processes.

Cross-scale integration. A third feature of Anthropocene risk relates to the dynamic integration among spatial, temporal and other scales. As cross-scale anthropogenic changes interact at both large and small scales—as well as across short and long time horizons—new feedbacks emerge[23]. Such feedbacks give rise to the dynamic interaction of slow (that is, climate change) and fast (large forest fires, for example) changes, which can trigger nonlinear systemic change (tipping points or regime shifts), such as the potential irreversible shift from rainforest to savannah for the Amazon biome[24].

It should be noted that the sheer scale, spread and speed of human actions are changing the very operation of known slow and fast variables, such as rising temperatures, sea-level rise and species extinction[15]. As has been noted by Earth-system scientists, the impacts of human action are expanding rapidly into what has been denoted deep time. As an example, recent analyses indicate that the long-term dynamics of the Earth's climate system (that is, for the next ten millennia and beyond) will be determined by political decisions made in the next few years and decades. Global mean temperatures, sea-level rise and associated ecosystem changes continue to respond long after the stabilization of radiative forcing, resulting in numerous committed changes in the Earth system thousands of years into the future. This lag in effects, the existence of feedbacks, connections between subsystems, and nonlinearities

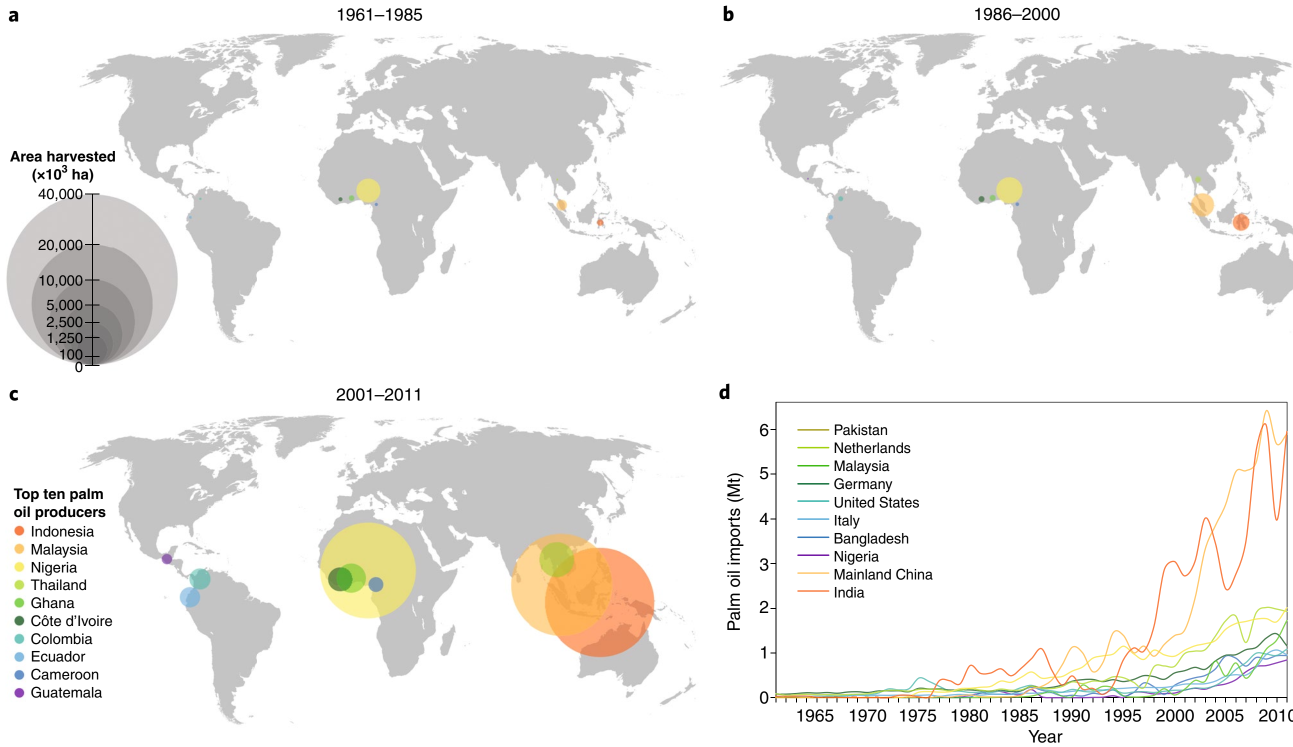

Fig. 2 | Harvesting and imports of palm oil for the period 1961 to 2011. a–c, Area harvested in the top ten palm-oil-producing countries over the periods 1961–1985 (**a**), 1986–2000 (**b**) and 2001–2011 (**c**). **d**, Imports for the top ten palm-oil-consuming countries over the same time period. Data from FAOSTAT (http://faostat3.fao.org/faostat-gateway/go/to/home/E).

allow for very complex temporal interactions among decision-making, environmental change and its implications for human well-being. Understanding such dynamic interactions, and how to prepare for and deal with them, is central for the governance of Anthropocene risk.

Four cases of Anthropocene risk

We illustrate Anthropocene risk using the following four case studies. We use these to explore Anthropogenic changes, global social–ecological connectivity and complex, cross-scale integration, and highlight risks ranging from short-term (immediate) to very-long-term (>500 yr) time horizons. These four cases demonstrate different aspects of Anthropocene risk that are not normally included in standard discussions about systemic risks, and explicitly emphasize examples outside of North America and Europe. Within each case, we provide a specific example and then widen our focus to explore various aspects of that Anthropocene risk.

Moisture recycling teleconnections. Millions of farms in the Indian subcontinent depend on groundwater irrigation[21]. Irrigation rates have increased since the 1990s, leading to the need for deeper, stronger pumps to extract water[25]. Agricultural productivity has been largely maintained through subsidized fuel costs and an increased technical ability to extract deep water[25]. However, groundwater-irrigated agricultural systems have the potential for collapse, due to prohibitive energy prices, exhaustion of wells and salinization of soils[25]. The large regional scale of this irrigated agriculture has profound impacts on the local and regional water cycle, particularly in terms of the influence on evaporation to the atmosphere and subsequent moisture flows to specific parts of the planet[26]. Hydrological analysis shows that irrigation in India contributes a substantial fraction (up to 40% in some months) of precipitation falling in East Africa[27]. Thus, the social–ecological systems that are producing food in India can have a cross-scale, teleconnected impact on rainfed systems in East Africa (Fig. 3a).

East African societies are highly dependent on rainfed ecosystems for agriculture, livestock forage and off-farm ecosystem services[28]. Many of these societies already operate at the hydrological margins, where small reductions in rainfall could lead to very large consequences such as crop failure, livestock death or drought-related hazards such as fire[28]. Some communities may be able to respond to these environmental changes by transforming to other livelihood strategies[29], or by finding ways to better capture and utilize existing rainfall and ground- and surface water. However, many communities and individuals will be unable to transform, and negative outcomes such as food shortage, forced migration and conflict over scarce resources are likely[3].

As a result of the intensification of irrigation contributing to rainfall in East Africa, farmers and pastoralists may have already adjusted their practices to the current teleconnection (that is, a social–ecological 'lock-in' under contemporary biophysical conditions[30]). The situation therefore presents a delicate dilemma: if communities in India improve sustainable agriculture practices (reduced irrigation and groundwater depletion), then pastoralists and farmers in Africa could suffer. This case of Anthropocene risk highlights how economic globalization has driven biogeophysical changes, leading to a new kind of systemic risk.

Aquaculture and locally stranded assets. Aquaculture is perhaps the most vibrant food sector in the world[31] with Southeast Asia particularly dominant, accounting for almost 89% of global aquaculture production between the 1990s and 2010s[32]. The reliance of

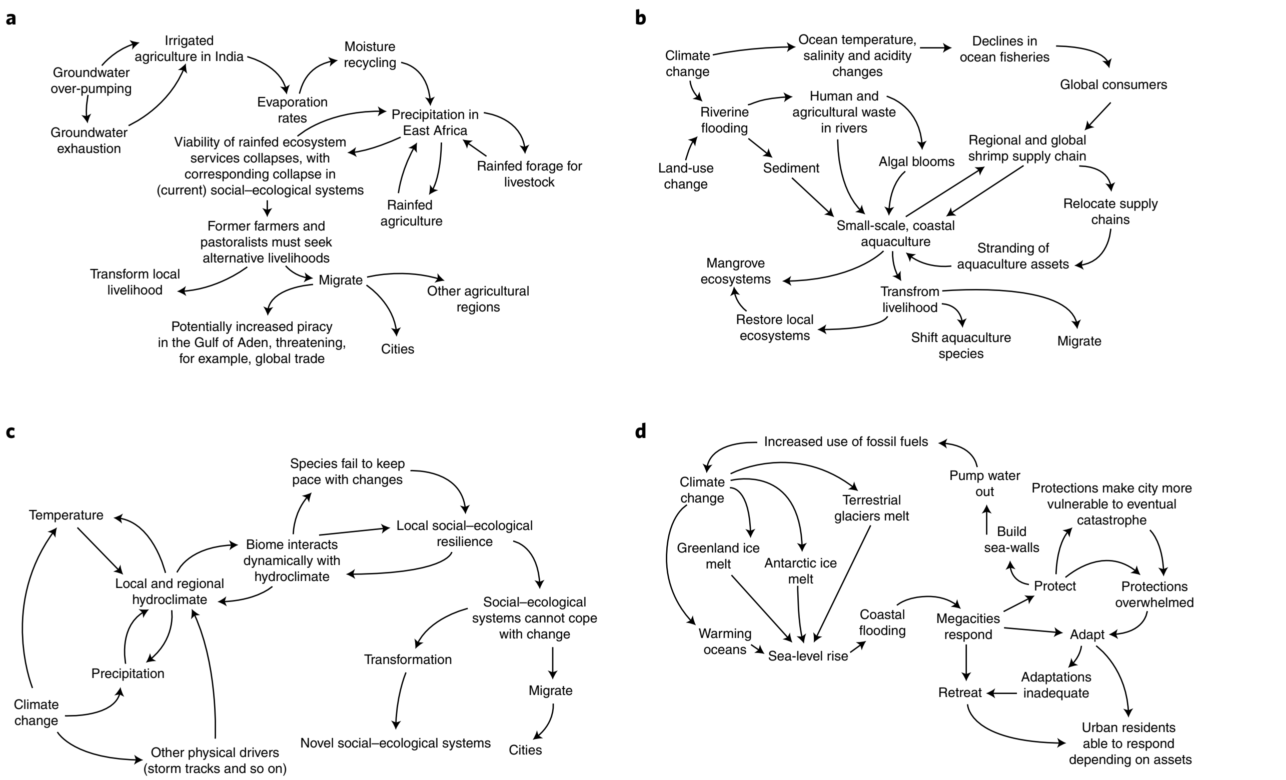

Fig. 3 | System diagrams. a, Moisture recycling teleconnections. **b**, Aquaculture and stranded assets. **c**, Biome migration in the Sahel. **d**, Sea-level rise and coastal cities.

aquaculture on terrestrial crops and wild fish for feeds, its dependence on freshwater and land for aquaculture sites, and its broad array of environmental impacts, strongly call for government policies to provide adequate incentives for resource efficiency, equity and environmental protection[31].

In the central coast of Vietnam, a consequence of the expansion of aquaculture is a vast denuding of coastal vegetation, especially mangroves. Aquaculture livelihoods are increasingly at risk owing to: increased sediment loads from upstream flooding, sand mining and human settlements; inundation from coastal storms, especially typhoons; and the loss of local habitat and nutrient cycling due to hydropower development[33]. Slow dynamics, including gradual sea-level rise and increased flood magnitudes, also threaten these livelihood strategies (Fig. 3b). These local interactions connect with regional and global dynamics, such as shifts in global demand for locally grown species or cheaper suppliers becoming available elsewhere, which leads to local asset stranding (that is, the removal of supply chains), rendering aquaculture assets (fencing, nets, boats) sources of debt as opposed to wealth[32]. Likewise, pollution from intensive aquaculture may also prevent aquaculture sites from being used for other purposes, leading to a pollution lock in-effect[30].

There are potential pathways by which local disturbances in aquaculture could scale up to national-, regional- or even global-scale impacts. First, farmed species can become incubators of diseases[34] that may spread to other farmed species, and combatting disease with antibiotics is causing antimicrobial resistance, thereby challenging human health. This presents a significant threat to regional aquaculture food safety and security[35]. Second, populations of farmed species have interbred with wild populations, leading to a weakening of hardiness to conditions in the normal life cycle of wild species in these locations[31]. Spatially, aquaculture competes with other uses of aquatic spaces, leading to increasing removal of wild lake ecosystems and mangroves, creating much less resilient systems. This confluence of global demand and site specificity means that tropical coastlines in the rapidly developing world, particularly those with weak environmental regulations, are particularly vulnerable to this Anthropocene risk[31].

Biome migration in the Sahel. Without rapid mitigation, climate change will perturb the current global distribution of biomes[36]. Temperature stress is a key determinant of the types of plants and distributions of ecological communities that can grow in different parts of the world[37]. As the entire planet warms, biomes tend to migrate to cooler regions (north, south or upwards along elevation gradients) by natural seed dispersal, human-assisted seed dispersal or physical transplanting[37]. Using climate-model temperatures and ecosystem temperature tolerance, the 'velocity of climate change' can be calculated[36]: the speed that a given biome needs to move to remain in an ecologically viable niche. However, given that ecosystems can also respond in an abrupt, nonlinear fashion[24], biome migration is also expected to occur in bursts or shocks, depending on the scale and nature of stress.

In the Sahel, climate change will probably lead to a drying trend[37], as well as increasing temperatures[38] (Fig. 3c). Predictions of specific ecosystem responses have high uncertainties owing to the range of biophysical and social drivers in play, yet some general conclusions may be drawn about biomes in the Sahel. First, it seems that desert areas are likely to encroach further south with current open shrubland areas becoming either desert or scrubland[36]. The temperature tolerances of local sorghum and millet varieties will probably be exceeded. Future societies face the options of importing heat-tolerant varieties, developing new varieties, switching crop types altogether or abandoning farming[39]. Although it is difficult to say what the future holds for the social–ecological systems in the Sahel, it seems likely that rainfed pastoralism will persist in some form due to the long-term adaptability of Sahelian pastoral societies[40]. Regardless, accelerated reconfigurations in ecosystem services are more likely to occur when exogenous changes in temperature and climate interact with local social–ecological systems[41].

Thus, social–ecological interactions may lead to nonlinear changes or complete transformations in Sahelian social–ecological systems[41]. These types of nonlinear changes are a near certainty in some communities very close to the edge of agricultural productivity in the northern Sahel, given the exposure to disruption of their livelihoods on so many fronts[29].

Ecosystem squeeze, the process of changes in the exogenous climate conditions that constrain a given ecosystem's range, is a relevant concept for Sahelian social–ecological systems owing to the inability to migrate en masse into the Sahara. This Anthropocene risk also has implications for larger scales of social and political organization, as people migrate to areas that are already heavily populated, thereby increasing the pressure on both social and ecological systems. Cross-scale relationships, such as local to national or urban to rural, may need to be redefined as social–ecological configurations react to ecosystem squeeze.

Sea-level rise and coastal cities. Global sea-level rise (SLR) is one of the most disastrous impacts of climate change due to the great importance of coastal settlements as hubs of trade, communications, government and culture. Ten per cent of humanity lives within 10 m of mean sea level[42], meaning that a very significant fraction of humanity is at risk of losing their homes and communities to the ocean in a few centuries. Most of the world's current megacities are likely to be underwater in 500 years, if not much sooner. This is less of a problem if cities proactively adapt or migrate away from coasts. However, cities are remarkably persistent in space and time. For example, London, Shanghai, Jakarta and Manila have all existed in their modern locations for 800 years or more.

Climate models project a large range in the magnitude of SLR through time, due in part to the substantial uncertainty about how the Earth's ice sheets will behave in a changing climate[43]. However, the consistent finding is that if anthropogenic greenhouse gas emissions are not controlled in the near term, the thermal expansion of ocean water combined with the release of freshwater from the Greenland and Antarctic ice sheets and continental mountain glaciers will lead to considerable SLR. Current estimates of SLR extend above 2 m by 2100[43]. In the long-term, however, palaeoclimate records are important sources of evidence, and these suggest an equilibrium rise of at least 6 m associated with contemporary CO_2 concentrations[44]. There is therefore a mismatch in model projections of SLR[43,45] and the palaeoclimate record in terms of long-term SLR[44], potentially suggesting an underestimation—or ignorance—of cryosphere tipping points. Regardless, even the SLR estimate of 2 m by 2100 will require unprecedented rates of adaptation (Fig. 3d). Furthermore, the poorest residents of low-lying megacities are most exposed to geophysical hazards, most marginalized by political and economic programmes and often targeted as scapegoats for other policy failures, such as the Makako community in Lagos, Nigeria[46].

Despite the coastal defences erected by cities, projections suggest that most, if not all, will eventually be overwhelmed by the inexorable increases in global sea level, leading to retreat from coastlines and migration inland. The impacts of SLR on cities are particularly concerning given current trends towards rapid population growth coupled with urbanization[43]. The vulnerability of cities to disease outbreak and disasters even with small rises in sea level (as seen through the impact of recent extreme weather events such as Hurricane Harvey and typhoon Haiyan) further demonstrates the need to better understand the Anthropocene risks they face[47].

Foreknowledge of the impacts associated with SLR does not, on its own, trigger action to proactively adapt. However, global insurance markets may force planning decisions as insurance companies consider withdrawing mortgage lending support. When this withdrawal happens on a large scale there will probably be significant direct consequences for the uninsured property owners and their cities. Here, the consequences of centuries of unfair and unjust housing practices will be painfully revealed throughout the world. Given that the most affected communities are systematically precluded from political, economic and social avenues for meaningful Earth-system-level solutions, SLR may be the quintessential example of an ignored Anthropocene risk[19].

More broadly, perhaps the biggest gamble the world's powerful are making in the twenty-first century is the assumption that the ocean will continue to function as it has during the Holocene. For example, the ocean absorbs more than 90% of the excess heat that humans put into the Earth system. Changes in ocean functioning are pervasive and potentially affect all aspects of the Earth system, challenging inclusion within specific examples of Anthropocene risk.

Discussion

The distinguishing characteristics and complexity of four Anthropocene risks have been briefly described. We now discuss several considerations for advancing the concept of Anthropocene risk, with a focus on governance, social injustice, concentration of influence and supranational power.

Is Anthropocene risk governance possible? Typical risk management is based on a strategy of prepare, detect, respond and repeat, with recent evolutions including elements of resilience theory (such as adaptive management and continuous learning) to enhance capacity[48]. Yet, Anthropocene risks, by their very definition, present a challenge to this ability to detect and prepare for risks and, importantly, to act on them. The Earth-system governance community has identified key challenges that are particularly relevant in Anthropocene risk, including: governance architecture, alternative forms of agency beyond nationality, the accountability of governance in a transnational context and who has access to power[49,50]. This alludes to fundamental issues of equity in governance, including: Who decides? Who has a seat at the table? Whose knowledge counts? Who benefits from the problem and who benefits from the solutions? These questions connect with historically relevant distributions of power and wealth, especially when considering the fossil-fuel-driven changes in the Anthropocene. These legacies of the accumulation of carbon-based wealth[19], for example, reinforce earlier Earth-system governance appeals for particular attention to accountability, legitimacy and access to decision-making[49].

Owing to the unavoidable deep uncertainties surrounding these risks, and the need for flexible management[5], a blending of quantitative (signal detection) and qualitative (iterative, shared learning dialogue) governance tools will be necessary. In the moisture recycling case as an example, even if groundwater collapse is detected, there is no guarantee that information describing impacts on East African rainfall will make it to the relevant communities, or that they will be able to manage a response that they find acceptable. The presence of both information and power asymmetries among social groups may lead to maladaptation and further exacerbate Anthropocene risk.

Foregrounding social inequality and injustice in the Anthropocene. Understanding the structure of networks (such as virtual water networks, global trade patterns[21]) and the behaviour of networks (propagating shocks in commodity chains, systematic exclusion of communities from Earth-system governance[3]) may prove key to characterizing Anthropocene risks. Recent work emphasizes the need to better understand the cross-scale pathways, interactions and feedbacks among inequality and the biosphere[13]. Furthermore, understanding multidimensional measures of inequality and their intersectional nature[51] is necessary to better map the complexity of social–ecological connections—especially those that are hidden at present by the focus on traditional measures of wealth inequality at aggregated scales[14]. Some of these measures of inequality must include historical perspectives of power imbalances. For example, the blithe proscription that the Syrian civil war owes its origin to climate change, or even drought, misses the deep internal legacy of planned policy and resettlement in certain parts of Syria. Moreover, it omits the legacy of European colonial powers dividing the entire Middle East region into politically expedient units for extracting natural resource wealth, leading to more than a century of strife. Much existing scholarship highlights how indigenous knowledge practices contest the very notion of a human-dominated world[52]. An important task for future Anthropocene-risk research is to learn about the role of humanity in Earth-system stewardship through these well-established counter-narratives of global collective use[53,54].

Uncovering key agents of Anthropocene risks. In complex systems, there is a tendency to centralize resources among a small group of agents[13]. Evidence suggests that key aspects of Anthropocene risks could be seen to be concentrated among just a handful of actors, especially with the shift from earlier geopolitically based global relations to contemporary arrangements among powerful, non-state actors. Österblom and colleagues[55] show the degree of concentration in global seafood production, putting considerable power to shape the world's oceans in the hands of just 13 multinational companies. Using global patent data, it has been revealed that ownership of a large proportion of marine biodiversity exists in the hands of a few countries and major corporations[56]. Likewise, global agricultural production is concentrated among a very finite group of actors—with nearly half of the commercial seed market controlled by three companies in 2007, seven companies controlling nearly the entire fertilizer market and just five companies controlling nearly 70% of the agrochemical market[57]. From the Earth-system perspective, a small handful of global asset managers retain considerable influence on climate stability, due to their expanding equity ownership globally[6].

Justice in a time of supranational connectivity. In the Anthropocene, the historical delineation of winners and losers becomes blurred as the supranational connective nature of wins and losses shifts across space and time. Put another way, a winner today could well be a loser tomorrow. However, the ability of certain powerful entities to deploy social–ecologically destructive capacity in concentrated bursts can lead to a mismatch in the initiators and victims of Anthropocene risks[22]. For example, the direct side effect of palm expansion includes deforestation methods that lead to extensive and persistent peatland fire, as well as substantial methane emissions that are distributed regionally and globally[58]. Likewise, the complexity of power imbalances within some Anthropocene risks leads to slippery solutions. For example, the revelation of a vast slave industry in Thailand supporting the fishing industry, leveraged by kidnapping and migrant flows, has not on its own changed the practice[59]. This is partly due to cultural disconnect between the slaves and consumers, as well as the inability of national and international institutions to meaningfully halt the practices that lead to the problem. Although these issues may seem peripheral or secondary in typical debates about Earth-system risk, the failure to confront injustices may lead to unexpected systemic feedbacks related to inequality[13].

Considering the profound disconnect within global, social–ecological systems[59], there is a need for knowledge from beyond the typical Anthropocene ken[52–54], as well as from institutions that are "reimagining orthodox social institutional constructs", including conventional notions of international environmental law[50].

Conclusions

Anthropocene risk is a new approach for characterizing unprecedented crises of the twenty-first century and beyond. Anthropocene risks emerge from anthropogenically driven processes, interact with globally connected social–ecological systems and exhibit complex, cross-scale interactions. The key advantages of the Anthropocene risk framing are the emphasis on all scales (spatial, temporal and otherwise) and the explicit focus on incorporating the complex adaptive attributes of human–environment systems. Using four examples of Anthropocene risk, we illustrate different types of connections across space and time, as well as feedbacks among social–ecological and Earth-system processes. Ultimately, this work seeks to provide conceptual guidance for exploring nonlinear and rapidly changing systemic risks, especially in the face of compounding, exploitative human activity. We suggest that Anthropocene risk can unpack the biogeophysical and Earth-system aspects of emerging systemic risks, which are normally ignored by other systemic risk scholars, and bring insight as to how the future may unfold.

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Competing interests

The authors declare no competing interests.

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