

Shaping a resilient future in response to COVID-19

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Science today defines resilience as the capacity to live and develop with change and uncertainty, which is well beyond just the ability to ‘bounce back’ to the status quo. It involves the capacity to absorb shocks, avoid tipping points, navigate surprise and keep options alive, and the ability to innovate and transform in the face of crises and traps. Five attributes underlie this capacity: diversity, redundancy, connectivity, inclusivity and equity, and adaptive learning. There is a mismatch between the talk of resilience recovery after COVID-19 and the latest science, which calls for major efforts to align resilience thinking with sustainable development action.

The COVID-19 crisis has exposed the vulnerability of our global society to systemic risks¹. What started as a localized disease outbreak cascaded rapidly across regions and sectors, with massive impacts on global health, political systems, businesses and economies worldwide. Immediate responses such as protecting the vulnerable, safeguarding livelihoods and developing vaccines were critical to stifle the pandemic. However, COVID-19 is a harbinger of a new global risk landscape in the Anthropocene, and humanity will increasingly be facing similar cascading, cross-sectoral and global shocks^{2,3}. This new risk landscape is the result of massive human-driven changes to the Earth system, fuelled by unprecedented levels of hyper-connectivity in our world^{4,5}. Events such as pandemics, financial crashes and synchronized food shocks propagate more rapidly now than in the past, and with greater geographic spread⁶. These shocks intersect with one another, just as COVID-19 compounded locust outbreaks, flooding and geopolitical instability in the Horn of Africa. Can we respond now to build a truly resilient and sustainable future—one that reduces risks and is prepared and able to deal with shocks well beyond pandemics?

Resilience thinking emerged from ecology in the 1970s but has since been applied in other fields such as international development, health, food security, community planning and disaster management⁷. Resilience is now factored into practice, policy and business, including public health, risk management in the private sector, development and finance investments, and business strategies.

Consequently, definitions of resilience have proliferated^{8–13} (Supplementary Table 1). In many cases, resilience is still narrowly equated to ‘bouncing back’ after a disturbance¹⁴. This assumes that building resilience means making a system ‘robust’ and resistant to change, so that it can remain as it is despite stress or a disturbance. Other definitions of resilience focus on adaptive capacity and the conditions that not only enable people to minimize the consequences of, and recover from, changes, but also to adapt and take advantage of new opportunities¹⁵. A third category of resilience definitions takes an even broader perspective and emphasizes the importance of planetary boundaries and transformability (that is, the capacity to create a fundamentally new system when ecological, economic or social structures make the existing system untenable) to achieve just and sustainable futures¹⁶.

Recent advances in resilience science and practice provide insights on the attributes and types of intervention that can underpin truly resilient, and transformative, sustainable development that is integrated with our life-supporting biosphere^{17,18}. Now is the moment to start translating this progress into broader-scale action that builds resilient economies, societies and ecosystems in a post-COVID-19 world. To support this, we provide a clear operational definition of resilience and present five key attributes that underpin this definition. The erosion of these five attributes has paved the way for fragility towards systemic risks such as COVID-19. We present a suite of evidence-based

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BOX 1**Addressing resilience trade-offs**

A challenge for building resilience is to design and implement concrete policies and actions. Practitioners, policymakers and business leaders will need to confront and address multiple trade-offs.

Some trade-offs will be related to the resilience attributes themselves. For example, there is a trade-off in costs and benefits with increasing levels of connectivity, especially if diversity in the system is low⁴. Similarly, while diversity and redundancy are key building features of resilience, very high levels of these attributes can lead to system stagnation and overwhelming complexity, compromising resilience in the longer term. For instance, too much redundancy in organizations can increase administrative costs, reduce transparency and hamper entrepreneurial behaviours associated with resilience^{7,78}.

Another category of trade-offs emerges when resilience-building becomes narrowly focused on a particular disturbance. This strategy will work in the short-term, and against well-characterized and frequent types of disturbance, but it runs the risk of causing the system to lose resilience in other ways. For example, research on rice-farming systems in Nepal and Spain shows how a narrow resilience focus for dealing with relatively predictable social and environmental fluctuations created vulnerability to other long-term social–ecological changes^{79,80}. In a similar vein, interventions to support resilience to specific shocks may have unanticipated trade-offs with other goals of sustainable development, such as human well-being⁸¹. Following the Asian tsunami in 2004, new legislation in India and Sri Lanka sought to create buffer zones and build resilience to future tsunamis by prohibiting homes and businesses being rebuilt close to the coast. Although this reduced exposure to future tsunamis, the rehousing of coastal people, dependent on the sea, to isolated inland villages disrupted livelihoods and undermined well-being.

Other trade-offs are related to the perceived financial costs and benefits of resilience measures, and their distribution over time⁸². These trade-offs are in many instances driven by short-sighted cost–benefit analyses that magnify the pain of present costs and substantially downplay the future negative economic impacts from not building resilience to future systemic Anthropocene risks. Depending on how resilience is operationalized, it can also lead to spatial and equity trade-offs. Spatial trade-offs are related to geography and can occur when resilience plans or interventions in one location may impact another location. Equity trade-offs refer to the distribution of benefits, losses and risks from decisions across groups. For example, there are trade-offs in which the resilience of some people's livelihoods may result in the increased vulnerability of others.

interventions that can enhance these attributes and operationalize response strategies towards a resilient and sustainable post-pandemic world. Many of these interventions have multiple benefits, and while they can lead to resilience trade-offs (Box 1), we showcase how their implementation is already occurring in different contexts, scales and sectors around the world.

Resilience in COVID-19 recovery plans

We begin by providing a quick stocktake of how the COVID-19 recovery plans of major policy actors (for example, the United Nations (UN), the International Monetary Fund and the European Union) and

national COVID-19 stimulus plans are integrating resilience-building as a key objective.

We surveyed the published response strategies to the COVID-19 pandemic of 16 prominent intergovernmental and non-governmental organizations between June 2020 and July 2021 (Supplementary Text 1). These organizations are all regionally and globally prominent at influencing policy and financing, including making direct loans or investments to countries. While the majority of surveyed organizations explicitly mention resilience in their published response strategies, only four provide a definition of resilience (Table 1 and Supplementary Table 2.1). Furthermore, the majority of the published response strategies made no mention of the need for transformative action or the importance of staying within planetary (or biosphere) boundaries (Table 1 and Supplementary Table 2.2). While we welcome the broad proliferation of commitments by these major policy actors towards building resilience as an important objective of COVID-19 recovery plans, our findings reinforce previous research showing that resilience is often poorly articulated among international organizations and development agencies, and merely used as a general attribute for recovery or as a path to 'bounce back' as fast as possible^{10,18}. The importance of resilience capacities for living and developing with changing circumstances and uncertain futures is largely absent.

We also reviewed the first wave of COVID-19 stimulus plans and interventions of 66 Group of Twenty (G20) and Group of Vulnerable (V20) countries for integration of climate risks, adaptation and resilience, based on official documents, and statements between January and November 2020 (Supplementary Text 2 and Supplementary Table 3). Only 12 countries cited climate risk management and resilience as a core objective of COVID-19 stimulus plans, alongside jobs and growth (Fig. 1 and Supplementary Table 4). These 12 are Bangladesh, Barbados, Colombia, Fiji, Kenya, Kiribati, Nepal, Niger, the Philippines, South Korea, St. Lucia and Vanuatu. An additional five countries (Ethiopia, China, France, Samoa and the United Kingdom) and the European Union integrated climate risk and resilience into specific investments, but not as an explicit core objective of COVID-19 stimulus plans and interventions.

As things stand, these findings align with ongoing tracking that shows how current global fiscal support of over US\$20 trillion in response to COVID-19 is not yet building back a better, 'greener' and resilient future that ensures the capacity to sustain, or improve, human well-being in the face of systemic uncertainty, shocks and change (<https://recovery.smithschool.ox.ac.uk/tracking/>).

Resilience in the new risk landscape

The Anthropocene requires living with increasing uncertainty and turbulence. Resilience capacities for persisting, adapting and transforming are central in this context¹⁹. Here, we define resilience as having the capacities to live and develop with change and uncertainty. This definition includes applying the following: (1) adaptive capacities to absorb shocks and turbulence, and avoid unpleasant tipping points and regime shifts^{20,21}; (2) capacities to prepare for, learn from, and navigate uncertainty and surprise^{22,23}; (3) capacities for keeping options alive and creating space for innovation^{24,25}; and (4) capacities for systemic transformation in the face of crises and unsustainable development pathways and traps^{26,27}. Hence, resilience as defined here is a forward-looking approach. This is in stark contrast to resilience as recovery to the status quo. Our definition is grounded in an understanding that humans and nature are intertwined social–ecological systems¹⁶, where human well-being depends on the stability of the Earth system, and that a just and equitable world needs to operate within planetary boundaries. It emphasizes that social–ecological systems interact from local to global scales (from local ecosystems and communities to the world economy and Earth stability); local systems are constantly influenced by global dynamics and drivers, while the global scale is

Table 1 | Integration of resilience in the published COVID-19 response strategies of 16 major policy organizations

Organization	Resilience	Planetary boundaries and biosphere limits	Transformation	Links to specific resilience attributes
African Union	No reference to resilience. Strategy focuses on immediate emergency response to prevent severe illness and death, and minimize social disruption and the economic consequences of COVID-19.	No reference to planetary boundaries or broader biosphere limits.	No reference to transformation.	Adaptive learning.
African Development Bank	Resilience mentioned, but no definition of resilience is given. Strategy highlights importance of resilient and sustainable food systems and deployment of solar photovoltaic power systems for healthcare facilities and communities to ensure increased and resilient capacity.	No reference to planetary boundaries or broader biosphere limits.	No reference to transformation.	Redundancy, diversity, adaptive learning, inclusivity and equity.
African Union Development Agency–New Partnership for Africa’s Development	Resilience mentioned, but no definition of resilience is given. Strategy highlights a ‘resilience-based approach’ to enable member states to “predict, prevent, respond, and adapt to the underpinning challenges during and after the crisis”. It mentions the resilience of African economies to the shocks from COVID-19 from a fiscal and debt management perspective, and recognizes the compounding impact of COVID-19 with other risks, such as drought, peace and security-related risks.	No reference to planetary boundaries or broader biosphere limits.	No reference to transformation.	Redundancy, diversity, connectivity, adaptive learning, inclusivity and equity.
Asian Development Bank	Resilience mentioned, but no definition of resilience is given. Strategy highlights resilience-building by financing the emergency response to the immediate impacts of COVID-19 on both people and the economy. This includes expanding the scope of contingent disaster financing to include health-related emergencies.	No reference to planetary boundaries or broader biosphere limits.	No reference to transformation.	Diversity, inclusivity and equity.
International Monetary Fund	Resilience mentioned, but no definition of resilience is given. Resilience not heavily referenced in published strategy documents.	No reference to planetary boundaries or broader biosphere limits.	No reference to transformation.	Adaptive learning, inclusivity and equity.
World Bank Group	Resilience mentioned, but no definition of resilience is given. Strategy mentions resilience-relevant measures and focus on resilience to future shocks under the banner of ‘rebuilding better’, and the continued commitment to building human and natural capital and to preserving global public goods like public health, climate and biodiversity	No reference to planetary boundaries or broader biosphere limits, beyond reference to climate change.	No reference to transformation, beyond high-level reference made to economic transformation.	Redundancy, diversity, adaptive learning, inclusivity and equity.
World Trade Organization	Resilience mentioned, but no definition of resilience is given. Strategy refers to resilience as something that is being eroded by COVID-19, without explicitly stating what resilience is. Strategy focuses primarily on immediate impacts and solutions.	No reference to planetary boundaries or broader biosphere limits.	No reference to transformation.	Connectivity.
Islamic Development Bank	Resilience mentioned, but no definition of resilience is given. Strategy has strong emphasis on the actions that lead to resilient health and economic systems that can respond to future shocks. Focus of the strategy is primarily finance related, with no mention of nature, biodiversity, planetary boundaries or biosphere limits.	No reference to planetary boundaries or broader biosphere limits.	No reference to transformation, beyond high-level reference made to transforming the global financial system to institutionalize risk sharing.	Redundancy, diversity, connectivity, inclusivity and equity.
Organisation for Economic Co-operation and Development	Resilience mentioned, but no definition of resilience is given. Strategy makes strong references to resilience to climate change and building back better, with an emphasis on inclusive, more resilient societies with net-zero greenhouse gas emissions and reduced impact on nature. Includes the role of environmental health in enhancing resilience to pandemics. Strategy emphasizes interlinkage between the environmental crises and increased risk of future infectious diseases.	Strategy makes reference to several planetary boundaries and biosphere limits, such as climate change, air pollution, biodiversity loss and poor ocean health. Strategy emphasizes need for more ambitious policies on biodiversity loss and the restoration of ecosystems and ecosystem services, including through nature-based solutions.	No reference to transformation, beyond brief reference to the transformation of cities into liveable places.	Redundancy, diversity, connectivity, adaptive learning, inclusivity and equity.

Table 1 (continued) | Integration of resilience in the published COVID-19 response strategies of 16 major policy organizations

Organization	Resilience	Planetary boundaries and biosphere limits	Transformation	Links to specific resilience attributes
European Union	Resilience mentioned and defined as the ability not only to withstand and cope with challenges but also to undergo transitions in a sustainable, fair and democratic manner. Recovery and resilience priorities focus on environmental sustainability, productivity, fairness and macroeconomic stability. Strategy is strongly premised on climate investments and reforms, and investments to foster the digital transition.	No reference to planetary boundaries or broader biosphere limits, beyond mention of a green transition.	No reference to transformation, beyond brief reference to digital transformation.	Diversity, connectivity, inclusivity and equity.
Economic Commission for Latin America and the Caribbean	Resilience mentioned and applied with the planetary boundaries framework to contextualize sustainable and equitable development and recovery from the COVID-19 pandemic. Strong integration of climate change and environmental degradation into sustainable recovery from COVID-19, and broader regional priorities such as equity and access to finance.	Strategy makes explicit mention of the planetary boundaries framework, and uses it to contextualize sustainable and equitable development and recovery from the COVID-19 pandemic.	Transformation strongly referenced across the strategy, including business, finance, economic, social and environmental dimensions.	Redundancy, diversity, connectivity, inclusivity and equity.
UN	Resilience mentioned, but no definition of resilience given. However, several other UN agency frameworks of resilience are referenced. Resilience mainly mentioned in the context of community resilience, food, healthcare and education systems.	Several references to ecosystem health and human health being intertwined, and the need to halt biodiversity loss, pursue regenerative practices and “restore the balance between humans and nature”.	Transformation explicitly mentioned and conceptualized as process that leads to a better post-COVID-19 world by addressing underlying fragilities and identifying opportunities for transformative change towards more just, equal, and resilient societies and economies.	Redundancy, diversity, connectivity, adaptive learning, inclusivity and equity.
World Economic Forum	Resilience mentioned and defined as “a health system’s ability to absorb, adapt to, learn and recover from crises born of short-term shocks and accumulated stresses, in order to minimize their negative impact on population health and disruption caused to health services”.	No reference to planetary boundaries or broader biosphere limits, beyond mention of a green transition.	Strategy recognizes importance of resilient healthcare systems as having the capability to transform.	Redundancy, diversity, connectivity, adaptive learning, inclusivity and equity.
FAO	Resilience mentioned and primarily used in context of the resilience of food systems to shocks. Resilience is defined as entailing prevention, anticipation, impact mitigation, adaptation and preparedness in shock-prone and protracted crisis situations, including epidemics. Strategy creates effective linkages between short-, medium- and long-term needs and risk-informed interventions that address also root causes of risk and vulnerabilities.	Strategy emphasizes nature and ecosystems, ecosystem restoration, ecosystem services and nature-based solutions.	Strategy emphasizes actions to ‘build back better’ by catalysing food system transformations	Redundancy, diversity, connectivity, adaptive learning, inclusivity and equity.
World Business Council for Sustainable Development	Resilience mentioned and applied in relation to business models, economic recovery, supply chains and finance. The use of resilience is informed by the planetary boundaries framework, as well as several science-based reports from organizations such as the UN Environment Programme, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, and the International Union for Conservation of Nature. A strong emphasis is placed on sustainability and inclusion in business and scenario planning.	Strategy explicitly mentions planetary boundaries and vision of a world in which more than 9 billion people are able to live well, within planetary boundaries, by 2050.	Strategy strongly emphasizes transformation, with particular reference to transforming economies, business and finance, and creating an inclusive world within the planetary boundaries.	Redundancy, diversity, connectivity, adaptive learning, inclusivity and equity.

Integration of resilience (including concepts of planetary boundaries, biosphere limits and transformation) in the published response strategies of 16 prominent intergovernmental and non-governmental organizations. See Supplementary Tables 2.1 and 2.2 for more detailed information.

shaped by emerging local dynamics (such as the swift change in norms, consumption patterns and policies).

While much of the policy world has focused on recovery, risk mitigation and incremental adaptation to manage shocks and stresses, our definition of resilience highlights the need to specifically invest in strategies that integrate mitigation and adaptation

(for example, zero-carbon adaptations), and transformation to address the fundamental changes required to navigate the new risk landscape associated with the Anthropocene. We affirm that resilience is a precondition (that is, a necessary, but not sufficient, component) of sustainable development in an increasingly turbulent world.

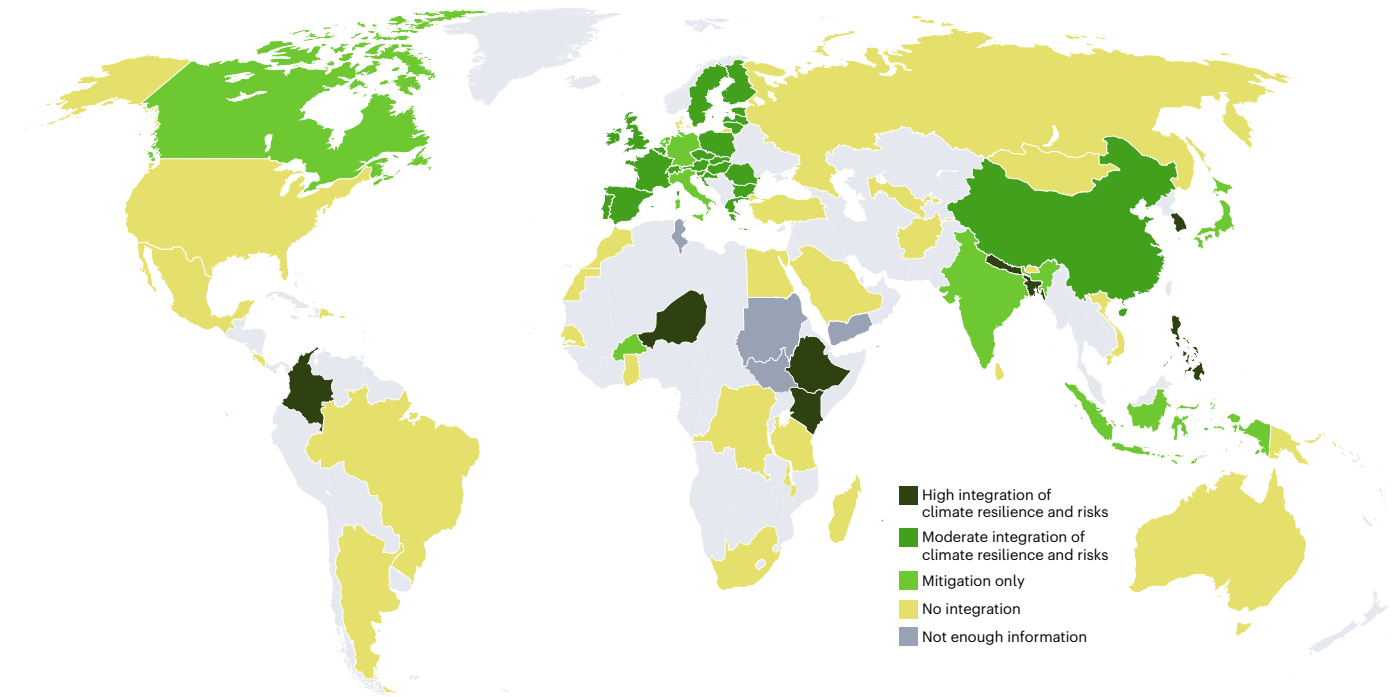


Fig. 1 | Degree of country-level integration of climate resilience in pandemic recovery plans. Countries are classified into the following four categories, based on levels of climate risk and resilience integration in their immediate COVID-19 stimulus packages (as of 5 November 2020): high integration of climate resilience and risks (these countries mentioned physical climate risks in their recovery packages, and placed them at the same level of importance as economic growth and job creation); moderate integration of climate resilience and risks (these

countries incorporated measures aimed at mitigating greenhouse gases as well as selective interventions that explicitly mentioned addressing physical climate risks); mitigation only (these countries only incorporated measures aimed at mitigating greenhouse gases); and no integration (these countries did not invest in climate-related initiatives, whether in mitigating greenhouse gases or addressing physical climate risks).

Five essential resilience attributes

Decades of interdisciplinary and transdisciplinary research have identified a number of strategies for enhancing resilience (Supplementary Text 3). Several studies have made major progress in synthesizing across disciplines, domains and systems to identify more focused lists of resilience-enhancing elements or principles^{21,28–30}. Building off these key studies, together with our own experiences and perspectives, we identify five key attributes that have been recurrently highlighted as essential for building and enhancing resilience (Fig. 2). We hope these attributes serve as a stimulus for further discussion and refinement. These five key attributes also provide a diagnostic lens to identify where critical fragilities exist. The first attribute is diversity (for example, biodiversity, livelihood strategies and institutional diversity) in all its forms. Diversity provides flexibility, through the ability to respond in multiple ways to systemic changes and shocks, and provides sources of innovation for novel conditions. Key dimensions of diversity have been lost in the Anthropocene. Biodiversity loss is occurring faster than at any time in human history, and is (together with wildlife trade and habitat loss) a primary driver of emerging novel zoonotic infectious diseases such as COVID-19 (ref. 31). Growing demand for harvestable biomass (food, fuel and fibre) has been met by converting much of the Earth’s biosphere into production ecosystems—ecosystems simplified and homogenized for the production of one or a few harvestable species⁴. Cultural diversity with skills and competencies for biosphere stewardship are eroding with one-size-fits-all policies of a globalized world³².

Diversity usually works in combination with redundancy. Redundancy, the second resilience attribute, ensures that there are multiple ways to secure critical functions in a system, such as provision of food or income, thereby providing ‘insurance’ and reducing single point failure. The capacity of ecosystems to contribute different options (for example, food, material, medicine) for supporting livelihoods

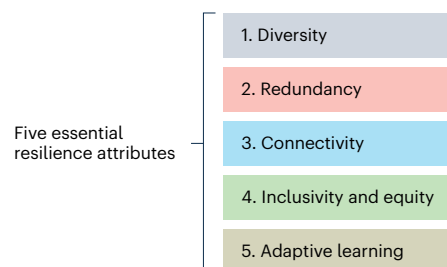


Fig. 2 | Key attributes for resilience building. Five key attributes that are essential for building and enhancing resilience.

and human well-being is being lost due to current rates of biodiversity decline³³. Similar erosion of redundancy can result from extreme economic specialization or highly concentrated supply chains. For example, in the context of the COVID-19 pandemic, countries that are heavily reliant on a single economic sector such as tourism have faced substantial economic hardship³⁴. Similarly, the grounding of the *Ever Given* ship in the Suez Canal exposed the low redundancy across global commodity supply chains. International trade in commodities is increasingly dependent on a small number of ‘chokepoints’—critical junctures on transport routes through which the majority of global trade passes through. A serious interruption at one or more of these chokepoints (such as the *Ever Given* incidence) can trigger massive delays, spoilage and transport costs, and conceivably even systemic consequences that could reach beyond food markets.

The third resilience attribute, connectivity, relates to the way and degree by which resources, information, species or people move or interact within social–ecological systems²⁸. Analysing social–ecological

systems as networks that consist of nodes and links has proved to be a fertile ground for exploring the relationship between connectivity and resilience^{35,36}. These networks can span sectoral, jurisdictional and geographical boundaries, connect various actors and institutions, and link human societies to the biosphere. Individual nodes can represent countries, actors, institutions, sectors, species or ecosystems, while links can capture collaboration, trade, policy overlap, environmental effects, species dispersals or trophic interactions. Connectivity is a dual-edged sword that can enhance resilience—for example, by maintaining an influx of important resources (such as food) when they are locally scarce or facilitating coordinated responses to shocks. However, the resilience of a system can be compromised if connectivity is too high, especially if nodes in the network are homogenous³⁷. For example, invasive species move easily across a simplified and overly connected landscape. Similarly, high levels of connectivity between banks (that all deployed similar risk-management models) led to a wave of bank collapses spreading from country to country, and paved the way for the 2007–2008 global financial crisis³⁸. Likewise, as connectivity and homogeneity in the global food system increase, shocks that were previously contained within a geographic area or a sector are becoming globally contagious and more prevalent⁴. The fragility of many countries' heavy reliance on globally connected food supply chains has been exposed due to the impacts of the pandemic, and recently substantially exacerbated by the Russian invasion of Ukraine challenging both domestic and global food supplies. Modularity (the extent to which within-subsystem interactions are more frequent than those between subsystems) can help contain disturbances by compartmentalizing social–ecological systems. For example, land management with prescribed fire can create a patchwork landscape with different fuel loads that limits the spread of the fire. Similarly, quarantine mechanisms may restrict the spread of epidemics or invasive species. Connectivity requires careful governance. Maintaining a balance between hyper-connectivity and modularity is key.

Fourth, a resilient social–ecological system is inclusive and equitable. Inclusive participation is important for building trust and facilitating collective action for responding to volatility and change³⁹. More equal societies (in terms of human development, income, access to resources) are less prone to instability and conflict^{40,41}. Unfortunately, inequalities across multiple dimensions (for example, economic, political, social, environmental and knowledge-based) are on the rise worldwide. Global inequalities today are at similar levels as during the peak of Western imperialism in the early twentieth century and have been further exacerbated by the pandemic^{42,43}. Rising inequalities is one of the key challenges of our time, eroding social resilience to shocks and stress, causing far-reaching ramifications for human well-being through impacts on economic stability, democratic processes, societal tension and conflict^{43,44}.

The final key attribute is adaptive learning—the ability to detect changes (especially slowly unfolding changes in system feedbacks and dynamics), learn from them and tailor management strategies accordingly. Current dominant governance and response structures, with focus on top-down approaches and short-term cycles, are unable to effectively deal with the interlocking and complex dynamics of the Anthropocene⁴⁵. For example, impacts of global warming started occurring long before they were detected, and even though these changes and their causes have been well-known for decades, there has been little effective policy response.

Building a resilient post-COVID-19 future

These attributes can help operationalize a resilient post-COVID-19 future. We provide examples of evidence-based interventions that can foster diversity and redundancy, manage connectivity, and increase inclusivity and equity in highly concentrated and connected sectors such as food, finance and energy (Table 2 and Supplementary Table 5). We recognize that there is some overlap between the interventions, and

the possibility of interactions (such as resilience trade-offs) between them (Box 1). We deliberately choose not to elaborate on those aspects, but instead focus on showcasing some of the growing number of existing initiatives, processes and mechanisms that are advancing the implementation of these interventions in different contexts, scales and sectors around the world (Table 2 and Supplementary Table 6). A resilient future in the Anthropocene will hinge on systemic changes in the fabric of legal, political and economic systems so that such initiatives and actions are rapidly, and successfully, amplified (Box 2).

Diversity

Diversifying national and regional energy mixes from highly centralized infrastructure (typically dependent on fossil fuels or large hydro-electric schemes) to more diverse and local renewable energy options will underpin resilient energy systems⁴⁶. Decentralized energy networks are rapidly spreading, based on super-efficient end-use appliances and low-cost photovoltaics, and several countries (for example, Germany and Morocco) are implementing such strategies on a national level (<http://www.energiewende-global.com/en/>)⁴⁷. Similarly, the resilience of food systems can be increased by promoting national crop diversity and transforming to diverse and sustainable forms of food production that reduce reliance on fossil fuels, water, pesticides and fertilizers^{48–50}. In India's state of Andhra Pradesh, 523,000 farmers have already converted 13% of productive agricultural area in the state into a local form of organic farming that conserves diversity, reduces anthropogenic inputs and costs, and improves farm viability⁵¹. A greater variety of livelihood opportunities can promote resilience in the face of adverse trends or sudden shocks⁵². Since 2014, the Sahel Adaptive Social Protection Program has supported livelihood diversification activities across six countries in the Sahel, and building household resilience to natural disasters, economic and financial crises, conflicts or forced displacement (<https://www.worldbank.org/en/programs/sahel-adaptive-social-protection-program-trust-fund>). Investments and policies that halt the degradation of biodiversity are crucial to resilience⁵³. Central here are government policies (such as fiscal and tax incentives to private and communal landowners) that can help maintain natural and biodiverse areas, along with international commitments such as the post-2020 global biodiversity framework for the Convention on Biological Diversity. Such strategies would reduce other systemic risks related to the destruction of biodiversity, including future outbreaks of zoonotic diseases⁵⁴.

Redundancy

Redundancy can be fostered through access to reliable and universal social safety net programmes. Such programmes have been shown to support food security, ensure continued access to resources and assets during times of shocks, and promote transformation towards climate and disaster resilient livelihood options^{55,56}. For example, Kenya's Hunger Safety Net Programme reaches over 100,000 households on a regular basis and is used during emergencies to transfer additional resources, reducing their vulnerability to shocks⁵⁷. Sustainably managing and restoring ecosystems will create important sources of 'insurance' options in the face of an uncertain future and maintains ecological services that buffer landscapes against extreme events. Insights from several ongoing initiatives of adaptive governance on natural capital (for example, various UN Educational, Scientific and Cultural Organization (UNESCO) Man and the Biosphere projects, and fisheries governance in the Southern Ocean) show that these are successful in managing multiple ecosystem services, monitoring and responding to ecosystem-wide changes at landscape and seascape levels, and have visible positive effects on natural capital and resilience⁵⁸. In a similar vein, creating flexibility by investing in a more diverse portfolio of regional and national economic activities that function as buffers and are differently impacted by shocks will promote redundancy⁵⁹. For instance, the Seychelles 'debt-for-nature' swap has allowed

Table 2 | Five key attributes that reinforce resilient systems

Attribute	Interventions to build resilience	Examples
Diversity	Support diverse economic opportunities and livelihoods.	The Sahel Adaptive Social Protection Program.
	Diversify and decentralize energy systems, including increased investment in on- and off-grid renewable energy options.	The German Energiewende programme.
	Halt the degradation of biodiversity and expansion of industrial agriculture into natural areas.	The Sustainable Biodiversity Stewardship programme in South Africa and the European Common Agricultural Policy.
	Transform to more diverse and systemic forms of biomass production that reduce reliance on inputs such as fossil fuels, water, fertilizers, pesticides and antibiotics.	Zero Budget Natural Farming in India's state of Andhra Pradesh.
	Increase national crop diversity so that countries have more options to navigate disruptions such as extreme weather events, outbreaks of pests, or economic and labour shocks.	The African Orphan Crops Consortium.
Redundancy	Introduce universal access to social safety net programmes that ensure marginalized communities can cope with unexpected shocks.	Kenya's Hunger Safety Net Programme.
	Support informal networks and civil society providing social buffers, ranging from remittances to healthcare and education.	Growing number of Village Savings and Loan Associations worldwide.
	Conserve, sustainably manage and restore natural ecosystems to ensure ecological safety nets.	Adaptive governance initiatives (for example, various UNESCO Man and the Biosphere projects and fisheries governance in the Southern Ocean) and nature-based solutions (for example, communal forestry projects in rural India and Zimbabwe) around the world.
	Maintain and expand national level options for accessing credit and stimulating economies (for example, expand fiscal space through debt relief, restructuring or debt swaps; expanding and maintaining currency swap lines with other countries).	The Seychelles 'debt-for-nature' swap.
	Maintain adequate reserves and alternative supply chains in key systems such as finance, food, energy and water.	Water harvesting programmes around the world (for example, India, sub-Saharan Africa and northeast Brazil).
Inclusivity and equity	Greatly increase the proportion of climate and development finance that reaches grassroots organizations and local communities.	SDI's Urban Poor Funds and the Huairou Commission's Community Resilience Funds.
	Ensure that development and adaptation planning places the needs of the most vulnerable at its centre and builds on existing grassroots structures, relationships and processes.	Kenya's County Climate Change Funds.
	Wealth redistribution programmes and taxes to build greater equality in unequal societies.	Spain's nationwide universal basic income programme.
	Build greater inclusivity and equity along value chains, including social safety nets for vulnerable informal and migrant workers.	Social safety net programme innovations across African countries.
	Expand access of communities and households, and in particular women and other vulnerable populations, to credit, risk sharing and savings facilities.	Microfinance and micro-credit initiatives in Bangladesh and Rwanda.
Connectivity and modularity	Stimulate local food production, especially in and around cities, to reduce systemic risks related to disruption of distant and highly concentrated global value chains.	The FAO's City Region Food System programme in Zambia, Colombia, Sri Lanka and Senegal.
	Invest in digital connectivity to connect the 47% of the world that is not able to easily access basic information and opportunities provided by big data and analytics.	COVID-19 Telehealth Program in the United States.
	Decentralize and modularize energy systems, connected in regional networks, to avoid systemic risks linked to large and overly centralized energy infrastructure.	Long-term energy strategy of Morocco.
	Support and amplify existing community connectivity and increase networks of community-based organizations to maintain the provision of basic services and programmes, especially for the most vulnerable.	SDI's Know your City initiative.
	Shift towards agile and adaptive decision-making processes that are guided by multiple probable scenarios of the future and not a stable-state view of the future.	Stress testing in financial institutions.
Adaptive learning	Maintain memory of responses to past crises and promote practices that enable social learning from novel crises.	National climate planning in Bangladesh and the Bangladesh Climate Change Trust Fund.
	Transform institutions and incentive structures across the science–business–policy–practice spectrum to reward collaborative learning processes that involve diverse types of expertise and knowledge to produce knowledge and pathways towards a sustainable future.	The Seafood Business for Ocean Stewardship.
	Invest in research, monitoring and knowledge management capacity to accelerate adaptive learning cycles needed to build resilience to systemic, compounding and unpredictable shocks.	Adaptive learning in social movements supporting transitions towards sustainable agriculture.

The second column contains evidence-based interventions that can strengthen these attributes and build resilience. The third column showcases examples of the growing number of existing initiatives, processes and mechanisms that are already advancing the implementation of these interventions in different contexts, scales and sectors around the world. The starting dates of these examples all precede the COVID-19 pandemic. Evidence for each of the interventions to build resilience are found in Supplementary Table 5 and detailed descriptions of the examples are found in Supplementary Table 6.

BOX 2

Amplifying and upscaling interventions towards resilience

Building resilience requires the growing number of existing efforts being advanced to implement resilience-nurturing interventions (Table 2 and Supplementary Table 6) to be rapidly amplified and upscaled. This requires an alignment with a robust definition of resilience, and shifting from single pilot efforts to systemic changes of the current fabric of legal, political and economic systems⁸³. Incremental change is no longer enough; instead, transformative structural change in global governance is needed⁸⁴. Three key tenets underpin these systemic changes.

Restructuring financial and economic systems

Global financial and economic systems need to be reformed away from the current narrow paradigm of economic growth to one that rewards sustainability and resilience^{85,86}. For example, central ministries of finance, planning and economy need to fully integrate resilience into long-term planning, investments and procurement. Governments and businesses need to adopt natural capital accounting and full costing of environmental externalities. Harmful subsidies and incentives (for example, those encouraging fossil fuel use and unsustainable resource extraction) must be replaced by regulations and incentives that can guide sustainable financial and investment decisions⁸⁷.

Rethinking how knowledge is created and used

Iterative and collaborative processes of knowledge co-production involve diverse types of expertise, knowledge and actors, which together produce context-specific knowledge and pathways towards a sustainable future⁸⁸. Such processes range from direct engagements between scientists and local communities, to the delivery of scientific knowledge and methods into multi-stakeholder arenas where it can provide a basis for learning and be translated into international negotiations⁸⁹.

Reconnecting people to nature

Safeguarding the biosphere from further degradation or collapse is a prerequisite for a resilient future for humanity⁹⁰. It requires a fundamental shift in perspectives and world views, so that human development is reconnected to the biosphere and humans become active stewards of the Earth system¹⁶. Biosphere stewardship is a learning-based process with a clear direction and vision, engaging different actors to collaborate and innovate across levels and scales as integral parts of the systems they govern. This includes identifying powerful actors, like financial investors or transnational corporations, and articulating key domains with which these actors need to engage to enable biosphere stewardship⁹¹. In operational terms, it implies a fundamental shift in governance from ruling over resource exploitation, to managing nature and its stability for human well-being. This covers multiple strands of social-ecological change such as deforestation, global warming, rising human densities and inequalities, simplified production systems, global market concentration, and hyper-connectivity in trade and transport⁹².

investment into ocean conservation to build the resilience of the ocean ecosystems on which the Seychelles is so dependent⁶⁰. With a rising frequency of extreme weather events, public-private partnerships

are scaling micro-credit and insurance systems for small-scale rain-fed farmers, with insurance payment schemes in case of extremes such as droughts and floods, contributing to add new soft-landing pads for vulnerable rural communities, thereby building climate resilience.

Connectivity

Approaches to maintain a balance between hyper-connectivity and modularity in food systems are being piloted by several initiatives, such as the Food and Agriculture Organization's (FAO's) City Region Food System programme in places like Zambia, Colombia, Sri Lanka and Senegal. A greater proportion of regional food production, especially in and around cities, can reduce systemic risks related to increased interconnectedness and reduced modularity in the global food system³⁵. It can allow countries and regions to be less susceptible to the disruption of distant and highly concentrated value chains, to dynamically balance the relative proportions of global and local sources depending on the circumstances, and allow access to the efficiency and price benefits of a global food system, while also incorporating the resilience benefits of more local food production⁶¹. Investing in digital connectivity (for example, broadband Internet access and online practices) has been shown to contribute to community resilience through building cultural capital in diverse ways, and to 'ripple effects' from online activities⁶². Similarly, supporting and amplifying existing community connectivity and increasing networks of community-based organizations can enhance resilience by fostering social learning and maintaining the provision of basic services and programmes, especially for the most vulnerable⁶³. Large-landscape conservation initiatives, like the Yellowstone to Yukon, that foster habitat and wildlife connectivity have been shown to enhance ecosystem resilience and achieve biodiversity conservation targets⁶⁴.

Inclusivity and equity

Fostering inclusivity and equity along value chains, with social safety nets for vulnerable informal and migrant workers, will enhance resilience by allowing value chains to regenerate more quickly following disruptions⁶⁵. Innovations, many led by technology, have resulted in rapid deployment of social safety nets in Africa, with every country across the continent now having at least one social safety net programme, and African countries spending on average 1.2% of gross domestic product on social safety nets compared with the global average of 1.6%⁶⁶. This will have social, economic and food security benefits. Likewise, more inclusive financial systems that expand access of communities and households, and in particular women and other vulnerable groups, to credit, risk sharing and savings facilities provide greater household financial security and resilience during crises⁶⁷. Policies that respond to systemic shocks (such as COVID-19) need to be inclusive and led by those at the frontlines of impacts. Local communities become agents of change when they have control over funding and when they lead interventions within said communities. For example, Slum Dwellers International's (SDI) Urban Poor Funds and the Huairou Commission's Community Resilience Funds are both examples of funds established and led by grassroots organizations to support and stimulate local resilience-building activities⁶³. Kenya's County Climate Change Funds enable ward- (community) and county-level climate change planning committees to shape the identification, prioritization and financing of adaptation projects. Community members are represented at each of these decision-making bodies and utilize participatory planning processes to identify their own priorities⁶⁸.

Adaptive learning

Investing in research, monitoring and knowledge management capacity will accelerate adaptive learning cycles needed to build resilience to systemic, compounding and unpredictable shocks⁶⁹. Social and institutional learning, in the form of maintaining memory of responses to past crises, can promote practices that foster resilience. For instance,

regular exposure to flooding and storms in Bangladesh has led to the creation of the Bangladesh Climate Change Trust Fund and the integration of climate change into all local and national planning processes, and across sectors. Fishing communities in Sumatra and Thailand survived the 2004 Asian tsunami thanks to inherited local knowledge of tsunamis and to institutional preparedness for disasters⁷⁰. Improving our ability to detect changes, including novel emergent dynamics, and continuously adapting and responding in a timely way is critical to managing emerging risks such as COVID-19. This requires substantial investments in institutions that focus on early warning across multiple sectors (for example, food, health, biophysical) and are internationally coordinated³¹. Economic and financial decision-making can become more adaptive if guided by multiple probable scenarios of the future and not a stable-state view of the future⁷¹. Such scenario-based approaches can help create agility during crises by allowing policymakers and local communities to more easily pivot towards alternative, and often community-based, solutions as needed.

Lessons from COVID-19

After decades of increasing frequency and amplitude of extreme events from rising global environmental change, COVID-19 may be the point in time when the world recognizes the fundamental shift from an Earth system of relative stability to a state of relative instability. In the Anthropocene, turbulence is the new normal. A key resilience insight from COVID-19 is that several strands of slow incremental change—deforestation, human encroachment into natural wildlife habitats, global warming, rising human densities and inequalities, simplified production systems, global market concentration to a few dominant actors in key economic segments, and hyper-connectivity in trade and transport—can interact and abruptly trigger far-reaching global crises. International organizations, governments, civil society and businesses must work to dismantle and phase out unwanted activities (such as fossil fuel subsidies, deforestation-intense economic activities) that underpin these risks⁷².

The implications are profound. Under stable conditions with limited shocks and stresses, building resilience may not be critical. Efficiency and optimization benefits are provided by highly centralized and concentrated global value chains delivering social benefits despite their brittleness. Such simplification of the global economy works as long as unpredictable shocks and stresses are rare. However, it breaks down when novel and unexpected shocks, like the unprecedented floods in Thailand in 2011 disrupting the global supply of computer hard drives (40% of hard drives are produced there), become more frequent or, as today, become the new normal.

Navigating the twenty-first century requires a fundamental reboot of the logic for economic progress and human development, away from a dominant belief in efficiency and optimization, to recognizing the importance of diversity and redundancy that spreads risks and increases capacities to deal with rising turbulence and uncertainty⁷³. In short, investing in social and environmental buffers, ranging from emergency stockpiles of medical equipment and means of producing food to diverse energy sources, and safeguarding capacities in nature to withstand stress and shocks.

Resilience research provides evidence that equity is central to building societies able to navigate turbulence and change. The experience from COVID-19, where vulnerable and marginalized groups have been disproportionately impacted, strengthens this evidence⁷⁴. The magnitude and severity of clusters of infection, mortality rates and ability to recover after the health crisis are all determined by the ability of societies to support the most vulnerable citizens. This equity aspect also requires a systemic shift in the global resilience research arena towards the Global South. Interestingly, evidence is emerging that poor communities may have resilience lessons to offer wealthier parts of societies in the handling of COVID-19. For example, despite high numbers of infections and severe economic hardships, COVID-19 has

revealed an Africa characterized by resilience rather than collapse and conflict⁷⁵. African countries effectively mobilized community health workers and communities to extend the reach, capacity and quality of their health systems⁷⁶. Vulnerable communities that are continuously impacted by relatively high but manageable stress levels (for example, hard-won experiences with previous health crises) may have crucial sources of resilience to deal with big crises when they hit. The Global South has great experience on which to draw. We need to leverage the massive potential of south–north and south–south knowledge transfer and collaboration to confront the huge challenges of the twenty-first century and ensure human well-being. Now is the time to start translating advancements in resilience science into broader-scale action that builds resilient and sustainable economies, societies and ecosystems in a post-COVID-19 world.

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J.R., A.V.N., N.M., R.B., C.F., S.H., N.K. and D.N. contributed to the conceptualization. J.R., A.V.N., L.W. and A.H. contributed to the formal analysis and investigation. J.R. and A.V.N. led the writing and revisions. N.M., R.B., C.F., S.H., N.K., D.N., A.H. and L.W. contributed to the writing and revisions.

Competing interests

The authors declare no competing interests.

Additional information

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