Nature for Climate Action: Nationally Determined Contributions

Policy strategies for managing deep uncertainty with deep resilience

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Suggested Citation

J. Cassin, K. Davis, J.H. Matthews (2021). Nature for Climate Action in the Nationally Determined Contributions. Forest Trends, Alliance for Global Water Adaptation.

Acknowledgements

The authors would like to acknowledge the following for valuable insights and feedback on a previous draft of this manuscript: Andrew Roby, Genevieve Bennet, Margaret Bowman, Cheyenne Coxon, Gena Gammie, Matthew McCartney, and Nathaniel Matthews. This report was in part made possible by support from the D.N. Batten Foundation.

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Foreword – Minister Meza, Costa Rica

For several decades now, Costa Rica has placed nature at the heart of its climate policies. Last year, as we updated our Nationally Determined Contribution, we set decarbonization and resilience as development models, and nature is a cornerstone of this double-pronged approach. As a country, we are building upon our decades-long crusade for nature to promote a decarbonized and resilient country.

Through decisive and statesmanlike policies and actions implemented since the 1980s, Costa Rica stopped and reverted the rampant deforestation we experienced in most of the 20th century. Areas under intensive pressure that had lost forest cover now stand as healthy and maturing ecosystems. Across governments and periods of economic growth and decline, we have maintained these policies. Forests shifted from being seen as a resource for extraction to an asset for investment.

As recognized by the awarding of the first Earthshot Prize, our economy and society have prospered with the growth and restoration of our investments in nature. And with time, climate change has provided new reasons for celebrating decisions made in the 1980s and 1990s. Even as our forests have sequestered carbon from the atmosphere, we also see these forests as assets providing, in the words of this white paper, adaptation services for water, livelihoods, sectors from energy to agriculture, our cities, for visitors worldwide to see and enjoy, and not least the incalculable value of forests for our indigenous communities. Our forests are indeed a source of wealth, but not as we envisioned wealth in the extractive 1950s and 1960s. They provide resilience because of their strength and integrity.

Costa Rica now hopes to replicate in our oceans the success we had on terrestrial ecosystems. In our 2020 NDC, we pledged to increase to 30% our maritime territory under conservation schemes and we are working to recognize the ecosystem services of blue carbon ecosystems.

As the authors note, deep resilience is a new term for actions that are being made in many places. By seeing the connections between problems, we can connect their solutions too. Deep resilience may take time but raising the quality of the solutions we develop is the real challenge that we face with climate change. We have a new term to affirm our actions for the past 30 years, and the resolve to share our lessons with our neighbors at COP26 and beyond.

Andrea Meza, Minister of Environment and Energy, Costa Rica

Foreword – Andrew Roby BEM, FCDO, United Kingdom

The accelerating pace of climate change is one of the most important divisions between this century and the last. The threat of more extreme impacts threatens to undermine the hard-earned progress of recent decades. Our investments in energy, agriculture, cities, health care, and water are often proving to be narrowly scripted in their roles in economies, with limited abilities to anticipate, much less respond to, emerging climate patterns. As a result, the systems we have created seem brittle, trapped in a rapidly receding climate, with uncertain paths to navigate into our future.

But if climate change has had a positive impact, then it must be in how so many of us are coming together, with a shared sense of risk. Ministries, sectors, and disciplines that once seemed irrelevant to one another, or even antagonistic, sense that they need a common vision for resilience. As old solutions seem increasingly incomplete, we are bringing new chairs to the table for new solutions that match the scale of the challenges we now face. The moment and stakes of COP26 are perhaps the most important symbols of these challenges and of these opportunities.

Deep resilience is an idea that reflects a profound transition almost impossible to imagine a decade or more ago. For too long, we have tried to solve problems by narrowing their focus, thereby also narrowing the range of solutions that are available. By embracing the uncertainties and spectrum of risks we face from climate change, we can redefine once-separate challenges as opportunities for integrated solutions. Systems thinking can lead to systemic solutions.

Indeed, deep resilience is also drawing from the insights of the "anti-fragility" movement, which sees shocks and stressors as critical to strengthening system resilience. A small flood helps us prepare for a larger flood, while Covid-19 tests our supply chains, so we can anticipate more significant disruptions. We must collectively "see" our systems if we are to strengthen them.

Deep resilience extends these insights by suggesting that nature-based solutions are often more tolerant of change and uncertainty than our traditional built solutions. Instead of seeing ecosystems as flows that feed our economies, deep resilience helps us see them as wellsprings whose flows catalyze resilience.

At COP26 the UK set out our new approach to water security; strengthening water adaptation in national policy (the AGWA Water Tracker for National Climate Planning), creating the political space to manage water sustainably (the Glasgow Fair Water Footprint Declaration, led by Water Witness International), and boosting water investment from the private sector (the Resilient Water Accelerator, led by WaterAid). Deep resilience thinking runs throughout our work, as do the principals of Locally Led Adaptation, whilst the Glasgow COP26 put nature at the heart of climate action.

To turn this thinking into action in the UK we have adopted the Enabling a Natural Capital Approach (ENCA) as supplementary guidance to HM Treasury's Green Book of appraisal and evaluation for public investment. If deep resilience is about tilting the scales in favor of nature-based solutions, then perhaps this is one way governments can start rewriting the rules of the grammar of economics, as Professor Dasgupta puts it[1].

Andrew Roby BEM, Senior Water Security Advisor, Climate and Environment Directorate, Foreign, Commonwealth & Development Office (FCDO), United Kingdom

[1] The Dasgupta Review – Independent Review on the Economics of Biodiversity, 2020.

Glossary

Adaptation involves adjustments in ecological, social, or economic systems in response to actual or expected climatic or other stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change.

Adaptation Services are the benefits to people from nature's capacity to moderate and adjust to variable conditions, including some climate changes, and continue to provide the ecosystem services that underpin individuals' and societies' capacity to adjust to changes.

Climate Proofing involves making infrastructure able to withstand climate change; being impervious or resistant to climate change.

Deep Uncertainty arises when stakeholders and decision-makers cannot agree on or cannot know how a particular system will work, how likely different possible future states of the system are, or how important different outcomes might be.

Deep Resilience, as a response to deep uncertainty, involves developing more durable, reinforcing, interlocking, and resilient solutions by finding synergies across sectors, institutions, and problems.

Gray Infrastructure is infrastructure that relies on constructed or engineered, technological solutions to societal programs, such as drinking water treatment plants, dams and reservoirs, seawalls, and levees.

Natural Infrastructure is an interconnected system of ecosystem components (water, soil, subsoil, vegetation, biodiversity) that performs one or more functions that provide services or benefits to people: hydrological regulation, carbon sequestration, flood mitigation, climate regulation or erosion control.

Nature-based Solutions are living solutions inspired by, supported by, and using nature to address societal challenges in a resource efficient and adaptable manner, simultaneously providing economic, social, and environmental benefits; they ensure or restore the functions of natural infrastructure.

Persistence involves resistance and recovery in the face of brief disruptions. Persistence is about the functions and processes of an institution or system continuing unchanged or with a brief interruption.

Resilience encompasses the ability to absorb or withstand shocks and maintain function, including through reorganization, adaptive capacity, learning, and transformation. Resilience includes aspects of resistance to change, recovery from change (persistence), adjusting and adapting in the face of change (adaptation), and transformation to a new state while continuing to thrive when returning to the original state is not possible.

Resilience Strategy is a systematic approach to understanding and addressing drivers, shocks, and stresses.

Transformation is a fundamental shift in a social or ecological system in response to extreme changes or shocks that make the status quo untenable.

Key Messages

Current business as usual approaches to climate action will not be sufficient given the pace and extent of climate changes and the uncertainty surrounding climate change.

While aggressively reducing emissions, we must radically rethink how we approach climate adaptation if the world hopes to cope effectively with present and future climate impacts.

The pace and diversity of climate change presents “deep uncertainty” about future threats. Coping with climate change requires a new approach, moving beyond traditional sustainability and adaptation approaches to “deep resilience” strategies.

Transformative changes that may be needed will be challenging to the status quo but a unique opportunity to reinvent how people and the planet can thrive.

Nature-based Solutions (NBS) are essential for successfully building deep resilience to climate change impacts; Nationally Determined Contributions (NDCs) and National Adaptation Plans should prioritize NBS in adaptation measures.

To support effective, credible NDCs, this brief seeks to inform approaches to adaptation that can effectively support deep resilience by clarifying: 1) why we need to rethink how adaptation is approached and what climate coping measures the NDCs must consider; and 2) why nature-based solutions will be central to coping effectively with climate change.

Because NDCs as currently formulated lack clarity on pathways and targets for implementing NBS to support adaptation, a companion piece will delve into guidance to support implementation, or how to operationalize NBS within the NDCs.

As country commitments spurred by COP26 are expanded and renewed, there is an opportunity to use NDCs — their framing, priorities, and implementation — to acknowledge the issues of deep uncertainty and to integrate deep resilience in programs, investments, and projects that can align with investors, civil society, donors, and resource managers.

Accelerating Climate Action through Nature and Water

Failing to reduce greenhouse gas (GHG) emissions is one of the greatest risks facing the world today. However, even dramatic cuts in emissions at this stage will only begin to slow the rate of climate change.[2] As of the middle of 2021, ever dramatic impacts of climate change are already here, and we need to aggressively cope with additional impacts that will occur in the coming decades, potentially even centuries.

Because the water cycle is tightly linked with climate change, people will feel the effects of climate change mostly through water: droughts, floods, disrupted supply chains, fires, and intense storms. At the same time, water provision is critical for economic development, underpinning food security, energy generation, viable cities, health, and water-based transportation. There is an increasingly pressing need to identify and implement climate coping measures that can help build greater resilience to water-related climate impacts in both engineered and natural water systems. Water enables adaptation across other sectors and therefore water can also be seen as the medium of positive change. According to the Global Commission on Adaptation report, *Adaptation's Thirst: Accelerating the convergence of water and climate action,* "If we can build resilience by managing water, we can move from a reactive, defensive approach to climate change to imagining how we can thrive."

Climate extremes, such as floods and droughts, are intensifying and occurring at an increasing rate, currently outpacing our ability to adjust or cope with their impacts. The spring and summer of 2021 saw devastating floods in Zhenzhou China, New York, New Jersey, Tennessee, and Germany, with hundreds of lives lost in Germany alone. Once-in-a-millennium heat waves in Oregon, Washington, and British Columbia, deep long-duration droughts in the Horn of Africa and the Southwestern US, and massive wildfires in California and Greece are just some of the flashing red lights of this year.

In the world of national and global climate policy, the Paris Agreement from 2015 becomes an active, living document in 2021 as countries begin to implement their climate mitigation and adaptation commitments as expressed in their climate plans, or Nationally Determined Contributions (NDCs). But these NDCs vary widely in quality and ambition. Converting NDCs into operational priorities and projects is expected to be difficult. The world is relying on these NDCs to deliver on both mitigation and adaptation; adaptation is especially challenging to define in practice.

Coping with climate change will require shifting away from business as usual along two dimensions. Conceptually, we must recognize the deep uncertainties surrounding climate change and move beyond traditional conceptions of sustainability and adaptation to embrace concepts of "deep resilience" (see Text Box 1). Are we simply reacting to climate impacts, or are we redefining growth and prosperity for an age of ongoing change? Operationally, nature-based solutions (NBS) must be embedded within the NDCs as strategic assets for ensuring deep economic, ecological, and community resilience.

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[2] The International Energy Agency estimates that current pledges to reduce GHG emissions will result in only a 40% decrease by 2050, far short of what is needed to keep temperatures below 2° C. https://iea.blob.core.windows.net/assets/9b20ea0c-ec63-4c5c-9b64-64a50fc66039/ExecutiveSummary_WorldEnergyOutlook2021.pdf

To support effective, credible implementation of NDCs that support deep resilience, this brief seeks to clarify: 1) why we need to rethink how adaptation is approached and what coping measures the NDCs must consider; and 2) why NBS will be central to coping effectively with climate change (Text Box 1). A companion piece will delve into guidance on implementation; how to operationalize NBS within the NDCs.

Text Box 1. Deep Resilience, Nature-based Solutions

Deep Resilience involves developing more durable, reinforcing, interlocking, and resilient solutions by finding synergies across sectors, institutions, and problems. Deep resilience suggests that more lasting, coherent solutions come from seeking synergies between once-divergent topics.

Nature-based Solutions

The European Commission defines Nature-based Solutions (NBS) as living solutions inspired by, continuously supported by, and using nature to address various societal challenges such as climate stabilization through removing carbon from the atmosphere, climate adaptation, water insecurity, biodiversity loss, and rural poverty, in a resource efficient and adaptable manner and to simultaneously provide economic, social, and environmental benefits. Nature-based solutions include both natural features (protected or restored ecosystems) and nature-based features that use or mimic the characteristics of ecosystems and natural processes but incorporate human management, design, engineering and/or construction to deliver or enhance beneficial services. Examples of NBS include the conservation or protection of existing natural infrastructure such as wetland or forest conservation, as well as forest restoration, agroforestry, regenerative agriculture, riparian buffers, biocultural restoration, and urban forests. As an umbrella concept, NBS is closely related to ecosystem-based adaptation, ecosystem-based disaster risk reduction, and eco-engineering.

2021-2023: A Critical Window for Getting the NDCs 'Right'

The Paris Agreement requires all Parties to the United Nations Framework Convention on Climate Change (UNFCCC) to set out their post-2020 mitigation and adaptation actions and targets through the NDCs. Together these actions will determine whether the world will successfully achieve the critical goals of limiting global warming to 1.5° C above pre-industrial levels and "ensuring an adequate adaptation response"[3] that strengthens resilience and reduces vulnerability to climate impacts. Beginning in 2021, countries will be implementing their NDCs in five-year cycles. Robust and effective implementation over the next few years is essential to avoiding catastrophic climate change. While we must meet the mitigation targets in the NDCs and reduce emissions, the adaptation actions are also critical to address impacts from a world that is already warming at an unacceptable rate.[4]

[3] See Article 7 of the Paris Agreement: https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/new-elements-and-dimensions-of-adaptation-under-the-paris-agreement-article-7

[4] Recent estimates are that global temperatures have risen an average of 1.1° C since industrialization and that we will likely surpass 1.5° C in the next 20 years without radical changes; IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The

Few countries in their NDCs *explicitly* emphasize the potential for NBS for climate adaptation as cost-effective, flexible solutions that can complement other physical (gray infrastructure) and soft (policy) options. The updated NDCs have made some improvements in referencing NBS. However these references tend to be general goals or visions for NBS in mitigation or for "greening economies". Few cases exist of specific NBS investments that are linked to specific adaptation outcomes or measurable adaptation targets, leaving little guidance on incorporating NBS.[5] Given that many finance institutions are in the process of aligning climate funding with national climate priorities, NBS may be ignored or little used.

Silence in most current NDCs about the options for NBS is a potential flaw, especially for climate finance and as countries move to project development. According to UK Minister Lord Goldsmith,

> Our recent research suggests that the odds are currently stacked against infrastructure investment in nature due to our procedures…. And whilst now is the time to accelerate the use of nature-based solutions for water, we know it is no panacea, but we do need to rebalance the scales so that natural options are considered equally alongside traditional infrastructure.[6]

Rethinking Adaptation under Deep Uncertainty

We cannot prepare for climate change using the same approaches that we have used in the past. Indeed, past models of sustainability, design, and planning are being widely questioned as climate change accelerates. To plan for the future, we must radically rethink what we mean by adaptation and what responding to climate change really requires. Many institutions are transitioning from seeing adaptation as a way to "climate proof" existing programs and projects through minor adjustments, to seeing economic growth, poverty alleviation, and ecological and community resilience in profoundly new ways that embrace the inevitable changes to come, while still providing prosperity, security, and well-being for our economies, ecosystems, and communities.

Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, et al. (eds.)]. Cambridge University Press. In Press.

[5] Recent analyses of NBS in the NDCs show that more NDCs are referencing NBS but there are still few specifics on adaptation. An early analysis of NBS in the NDCs (in 2019) found that most (66%) of NDCs included mention of ecosystems or nature-based solutions for mitigation and/or adaptation. However, only a few (17%) of the NDCs that mention NBS actions for adaptation have set quantifiable targets. Similarly, few countries include NBS that deliver both mitigation and adaptation benefits. Most of the NBS actions are planned for future implementation and are conditional on international financial support. Bolivia is one of just a few countries that have identified multiple specific actions – eight specific action areas for NBS – accompanied by quantifiable targets such as strengthened carbon capture and storage or soil health. The just released synthesis of NDCs (September 21, 2021) and WWF's report on NBS in the updated NDCs (October 2021) shows that there have been some improvements in identifying specific actions and targets for NBS but these are still extremely limited, most of the focus remains on mitigation alone and on forest ecosystems so that the broad application of NBS from many ecosystem types to adaptation is still weak; *Nature-based Solutions in Nationally Determined Contributions: Synthesis and recommendations for enhancing climate ambition and action by 2020*. Gland, Switzerland and Oxford, UK; IUCN and University of Oxford; *Nationally determined contributions under the Paris Agreement*. Synthesis report by the secretariat. Advance Version, September 21, 2021. www.naturebasedsolutionsinitiative.org/wp-content/uploads/2019/09/NBS_in_Nationally_Determined_Contributions_final_web.pdf; https://wwfint.awsassets.panda.org/downloads/wwf_ndcs_for_nature_4th_edition.pdf.

[6] Rt Hon Lord Zac Goldsmith of Richmond Park, Minister for Pacific and the Environment, FCDO and Defra; 24 August 2020.

Coping with climate change presents at least three novel challenges for decision-makers:

1. Many climate shifts are unclear and difficult to predict in terms of scope, timing, and extent, making it even more difficult to understand and plan for climate impacts.
2. Even with perfect knowledge of climate change, climate impacts will differ by the pace and extent of change and by stress on human and natural systems.
3. Shocks and stresses to socio-economic and environmental systems will interact in complex ways, adding significantly to both uncertainty and extent of impacts. Other stressors such as the loss of forests, biodiversity loss, unsustainable groundwater extraction, and water pollution will all interact with climate change, increasing the severity of threats to well-being while also weakening the capacity of both social and natural systems to recover from stresses.

Most coping measures in the NDCs are not designed to address these challenges and most are targeted to more gradual and predictable changes, such as individual climate impacts or impacts on individual sectors, rather than considering multiple interacting environmental and social factors.[7] Historically, our infrastructure, planning, and development decisions have assumed that we know what the future will look like based on similarities to the past and that we can predict future conditions with enough precision to make detailed plans. What happens when the future is more vague, opaque, and unclear?

Multiple Types of Disruptions, Uncertainties, and Resilience Strategies

The pace and extent of climate-induced changes will influence our ability to cope (Text Box 2) and influence which strategies are appropriate depending on the type of disruptions we face (Text Box 3). Some changes will be gradual or incremental. For these, we can make reasonable predictions, at least for the near future and prepare in advance to adjust over time as conditions change. Most adaptation measures in the NDCs are designed to address these kinds of changes. However, other disruptions will occur rapidly and result in more extreme shocks or radical changes, and will be extremely difficult, if not impossible, to anticipate. Experts agree that the most severe impacts of climate change will result not from changes in average conditions (e.g., increase in mean temperatures) but from changes in the extremes such as deep and deadly heat waves, floods, and droughts.[8]

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[7] Individual drivers of climate impacts, such as more intense and variable precipitation that contributes to increased flooding or landslides, will intersect with many other social and environmental drivers, such as demographic and economic changes that increase food and economic insecurity, forcing farmers onto marginal lands and steeper slopes, increasing exposure and vulnerability of these farmers to climate impacts and exacerbating loss of forests and soil instability which in turn can impact downstream water supplies and security of downstream communities. The interaction of climate and other socio-economic changes makes assessing future conditions difficult and requires a systems approach, rather than single issue or single sector approach.

[8] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani et al. (eds.)]. Cambridge University Press. In Press.

Text Box 2. Shocks, stresses, and system changes are experienced in three general patterns:

1) **Short-term disruptions**: No major shift in conditions relative to the past or brief disruptions from the current state; many of these can be predicted, such as minor droughts of short duration.
2) **Gradual long-term disruption**: Gradual or incremental change in conditions that can often be anticipated in the near-term, such as sea level rise or decreasing annual precipitation.
3) **Sudden long-term disruptions**: Radical changes that can lead to major disruptions in a system. These events tend to be highly uncertain and nearly impossible to predict, such as frequent and intense heat waves combined with long-term drought; rapid loss of water storage in glaciers; changes in ocean currents that affect weather patterns over large areas; and shifts in the location, timing, and amount of monsoonal rainfall.

Adapted from: Chapagain et al. 2021. The Water Resilience Assessment Framework. Alliance for Global Water Adaptation, CEO Water Mandate, International Water Management Institute, Pacific Institute, and World Resources Institute.

All three types of disruptions can occur together; for example, long-term gradual declines in precipitation can be punctuated by short-term droughts and more extreme heat waves. The pattern of disruptions can also change over time as incremental changes cross tipping points into more extreme and rapid changes that result in novel conditions. For example, a period of gradual warming and drying can flip into deep and long-term drought conditions.

Traditional Approaches Do Not Account for Deep Uncertainty

Common definitions for adaptation and resilience implicitly assume that climate change will be both gradual over time and within relatively "normal" bounds that are not radically different from past conditions. The UNFCCC defines adaptation as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities." The UNFCCC defines resilience as "the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change."

In other words, the underlying assumptions are that we will be able to make incremental adjustments as conditions change and we will be able to bounce back to some normal, pre-stress conditions or persist in the face of some disruptions. We know that these assumptions are not true across all the three climate disruption patterns.

Different types of strategies for resilience are needed given the different types of climate disruptions society will face. Resilience includes aspects of returning to a previous state following a disruption (persistence or 'bouncing back'), incremental adjustments to change over time (adaptation), and reconstituting as a new system that can thrive under the new conditions when going back to a previous state or functionality is not possible (transformation or 'bouncing forward') (Text Box 3).

Text Box 3. Resilience Strategies Aligned with Different Disruption Patterns

As we respond to the deep uncertainty of climate changes, different strategies (or hybrids of these strategies) will be needed for coping with different types of disruptions.

Persistence involves resistance and recovery in the face of brief disruptions. Persistence is about the functions and processes of an institution or system continuing unchanged or with a brief interruption. Success under a persistence strategy looks like returning to the pre-shock conditions as quickly as possible or avoiding collapsing in the face of shocks. Most existing resilience or adaptation plans focus on persistence; it is also the explicit or implicit goal for most sustainability programs for people and ecosystems.

Adaptation differs fundamentally from persistence by assuming that tomorrow (or next month or next year) will be different than today, and that most of these changes are gradual and predictable (within certain bounds). In practical terms, successful adaptation means tracking change over time, especially gradual change, and taking the necessary action to address current and anticipated changes. Long-term changes to the system, such as population growth, sea-level rise, variability in precipitation, and urbanization are good examples of shocks and stresses that support adaptation strategies. In practice, an adaptation strategy often means focusing on incremental changes in the near term while looking ahead to when you may pass a threshold that leads to more significant kinds of changes.

Transformation is needed when big, hard-to-predict shifts occur. While adaptation guides you to prepare for incremental change, a transformation strategy is a result of a fundamental shift in a system (e.g., little or no rainfall for many years) or a significant change in the needs of a system (e.g., a need to shift completely from surface water to groundwater). While most parts of the world are now employing persistence or adaptation strategies, some regions are already facing novel conditions and are being forced to transform. This includes high-altitude areas (e.g., Andes, Himalayas), high latitude areas (e.g., Scandinavia, Russia, Canada), and regions very sensitive to inundation (e.g., low-lying coastal areas, small islands, river deltas). A transformation strategy typically requires reconsidering fundamental aspects of a system. Awareness of system vulnerabilities and opportunities is especially important, as disruptions in one part of the system may ripple and even amplify across other aspects.

Adapted from Chapagain et al., 2021, The Water Resilience Assessment Framework.

Climate change will comprise a dynamic mix of gradual long-term changes, short disruptions, and deep shocks. Resilience strategies therefore also need to be dynamic, and periods of transformation may alternate with periods of persistence and adaptation (Figure 1). The dynamic, complex, and uncertain nature of climate changes will require integrated and evolving sets of resilience strategies (Figure 2).

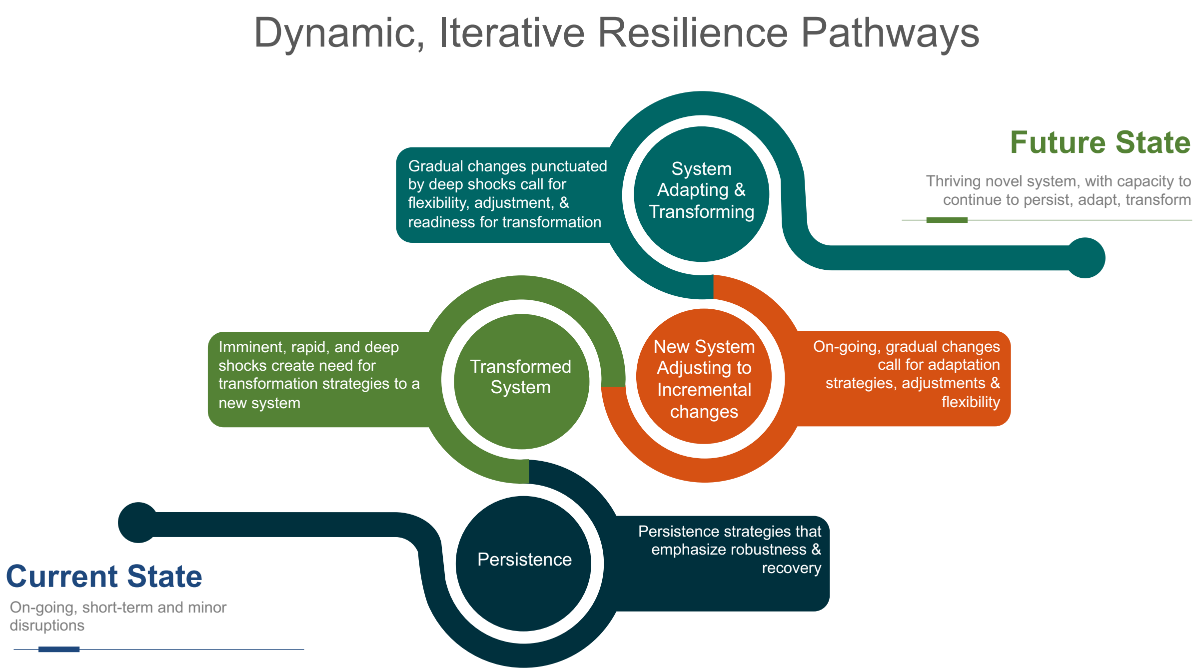

Figure 1. As the patterns of disruptions change over time, resilience strategies need to evolve along dynamic pathways.

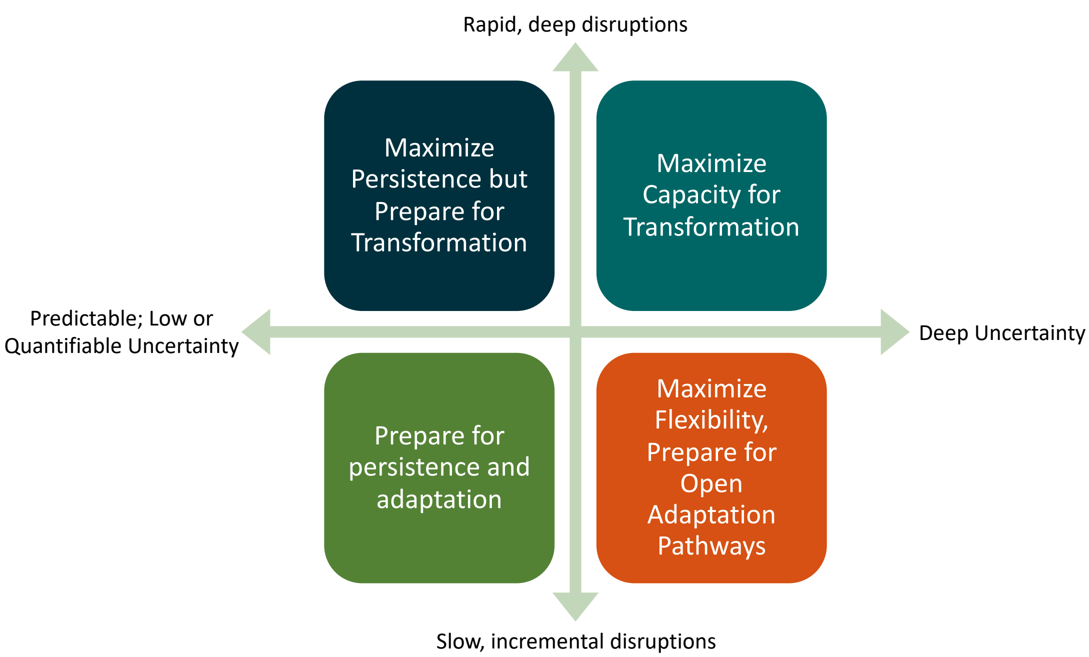

Figure 2. Resilience strategies aligned with the pace and extent of disruptions and the degree of uncertainty about future conditions.

Deep Uncertainty in Climate Change

More profound and longer-term climate disruptions, as well as the interaction of climate change with other stressors, will result in novel conditions that humanity has little or no experience dealing with. In the most extreme cases, humanity may have had little or no experience dealing with these conditions for millennia, such as extreme shifts occurring now around the Arctic Circle and in tropical glaciated mountains, such as the Andes and Himalayas. Biodiversity loss, alterations to hydrological systems, such as wetland loss or unsustainable groundwater extraction, disruptions to global supply chains, and ecosystem degradation will interact with climate change and challenge our ability to cope, especially if we try to address the changes individually rather than systemically. Climate coping mechanisms will need to address these complex and unpredictable intersecting challenges as well as their associated uncertainties.

The inefficacy of traditional planning and design approaches has recently become more widely clear to many decision-makers. The Covid-19 global pandemic, beginning in late 2019, served as a powerful reminder of the reality and major impact of a "black swan" event rippling across sectors and borders. In many countries, Covid-19 served as a real-time stress test for economic, social, and political systems, triggering additional ongoing shocks. The intersection of major climate shocks and the accumulation of compounding climate stressors promise more such events in coming decades.

In 2012, a team from the several universities, a development bank, and some technical resource management agencies wrote a paper describing "deep uncertainty" as a critical but largely ignored obstacle to a variety of economic development targets, including poverty alleviation, climate adaptation, disaster risk management, and infrastructure investment. Coping with climate change will require making decisions under deep uncertainty about the future. We cannot know with high levels of confidence what future climate conditions will be and how those conditions will affect critical human and natural systems (Text Box 4).

Deep Uncertainty Calls for Deep Resilience Thinking

Deep uncertainty is a big concern (or should be) for governments and investors such as the World Bank and other international institutions that fund long-lived assets that are intended to be "sustainable."[9] These institutions fund and support infrastructure, policy, and governance systems that are also locked in a matrix of social, economic, political, and technological shifts. Climate change is a major component of deep uncertainty, especially as it relates to the water cycle

[9] Sustainability and resilience are related concepts, and 'strong sustainability' may be more aligned with deep resilience than common usage of sustainability. Sustainability as applied is often associated with fixed targets such as amount of water stored for flood mitigation or water supply, meeting water delivery goals for predicted population growth, or hectares irrigated. Resilience is more about process – what happens when conditions change, where are we headed, and how to keep functioning when unexpected things happen. A focus on sustainability alone can impede resilience if adjusting fixed targets is not possible or extremely expensive. As such deep resilience is the more encompassing concept and does not reject sustainability goals such as intergenerational equity but can make these goals achievable.

because these water-related impacts are among the least certain, least predictable, and most climate sensitive.[10]

Text Box 4. Deep Uncertainty

Uncertainty arises in the gap between available knowledge and the knowledge that is needed to make the best choices for climate-relevant decisions around planning, design, resource management, and operations. Traditionally, uncertainty has been addressed by improving the information we have about future conditions or using statistical analysis to develop probabilities and confidence ranges about the likelihood of specific conditions or alternative futures. However, deep uncertainty arises when these options cannot substantially help improve decisions – when we don't know what we don't know. Deep uncertainty arises when stakeholders and decision-makers cannot agree on or cannot know how a particular system will work, how likely different possible future states of the system are, or how important different outcomes might be. We are not able to effectively predict future climate conditions or their impacts. While assessments of climate impacts are improving, it is still extremely difficult to predict even the range of possible future conditions with much confidence. Deep uncertainty describes situations where:

- The past is no longer a guide for what might happen in the future;
- We cannot know how likely very different alternative futures are;
- We cannot evaluate the value or the impact of different outcomes; and
- Decisions must be made over time under conditions of dynamic change.

Adapted from: Marchau et al., 2019. Decision making under deep uncertainty: from theory to practice. Springer Nature, Cham, Switzerland.

Though traditional methodologies for managing water sustainably — for energy, agriculture, cities, or ecosystems — take into account a level of uncertainty arising from natural variability, these traditional approaches are extremely inadequate in the face of climate change. Many more recent approaches are difficult to apply, highly specialized, or have not received widespread acceptance. For long-lived assets or systems, such as utilities, hospitals, roads, and irrigation facilities, investments can become "climate traps" or stranded assets with very limited or expensive options to adjust course, change operations, or update the investments.

For several years, a wide variety of groups have converged on addressing deep uncertainty by suggesting that we divide our knowledge into two boxes: one containing issues and impacts that merit decisive, robust interventions spanning a wide array of potential futures, and a second box containing all of the residual uncertainty, which we need to address by being flexible to avoid climate traps.

[10] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani et al. (eds.)]. Cambridge University Press. In Press.

Deep resilience has begun to emerge as a third response, which we define as developing more durable, resilient responses by expanding the set of problems being addressed to create reinforcing, interlocking, and synergistic solutions. Covid-19 has accelerated the interest in deep resilience approaches by exposing connections and vulnerabilities between health, supply chains, infrastructure and data systems, and social and governance processes. Major water disruptions typically have similar systemic vulnerabilities.

A Deep Resilience Approach

Our traditional approach is to focus on a problem narrowly, so we can define a challenge in a way that can be addressed through a discrete and well-bounded intervention. For example, if farmers are experiencing water scarcity, a storage dam or irrigation facility may be necessary. For coastal settlements, a seawall may be useful for tropical cyclones and storm surges. Indeed, engineers (and many others) are trained to "split" problems into more narrow, easily defined components to make them more tractable. Splitting into narrow components may lead to efficient solutions for a single aspect of a problem. Unfortunately, as our problems become more complex and deeply uncertain, splitting also reduces our ability to see new, emerging, or unusual challenges that may also be important — exactly the kinds of issues that characterize deep uncertainty. Splitting also reduces our ability to find more resilient, long-term solutions.

Deep resilience addresses uncertainties directly by "lumping" challenges together. As a practice, deep resilience contains a strong resonance with initiatives such as the German Federal Ministry for Economic Cooperation and Development's (BMZ) One Health, which recognizes that human health, ecological resilience, and climate change are inherently connected.

Importantly, a deep resilience approach requires both a broad view of how specific sets of issues or challenges are interlinked, as well as a more granular view of how systemic solutions in aggregate actually contribute to specific outcomes. In Udon Thani, the second largest city in Thailand, a team of local and international practitioners chose to see flood control, diminishing rice paddy irrigation, and marginal hydropower generation not as separate problems but as an opportunity to connect these issues into a single, integrated solution. The mayor of the city may have initiated this effort when he noted that the city's rapid growth was also a challenge to the natural beauty and livability of Udon Thani. As a result, the task force suggested the creation of a series of interconnected urban lakes, which could act as a means of both storing water (for irrigation and energy generation) and for capturing stormwaters. In effect, the urban lakes brought together a wide range of functions through engineered NBS. In addition, given the mayor's interest in ensuring a high quality of life in the city, the significant co-benefits of these lakes have increased property values, improved the health of many citizens, and integrated ecosystems within an urban fabric.

To really craft durable, systemic resilience strategies, the individual strategies for persistence, adaptation, and transformation must be embedded within a deep resilience frame (Figure 3).

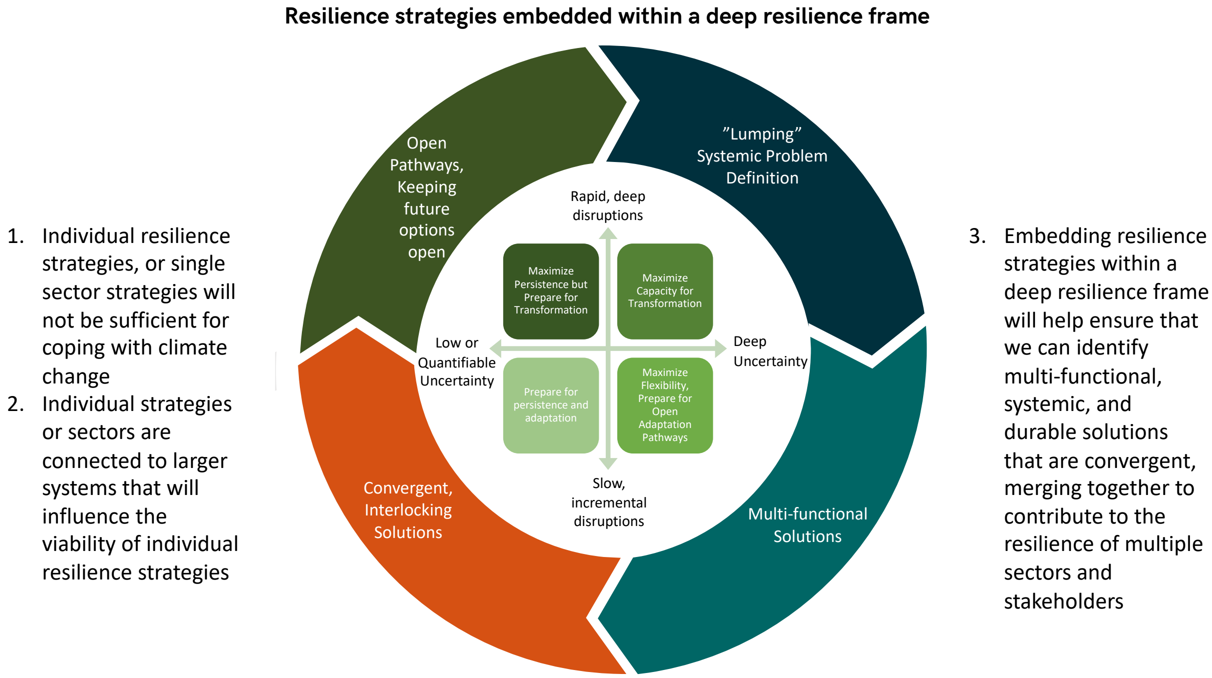

Figure 3. Embedding resilience strategies within a deep resilience frame.

Nature-based Solutions are Critical for Successful Resilience Strategies

The success of resilience strategies will depend on how well we develop interlocking solutions that are woven together, moving beyond the silos of distinct agencies, programs, sectors, and disciplines. While hard (gray infrastructure) and soft approaches, such as better early warning systems for hazards, have been the most prevalent coping measures to date, there is growing interest in the potential for NBS. Nature-based solutions are multi-functional by nature; they can address the interdependent challenges of ecosystem degradation, biodiversity loss, human well-being, and climate change together and lend themselves inherently to deep resilience. While NBS will be essential for coping with climate change, NBS themselves are vulnerable to climate impacts, and this must be considered in developing resilience strategies.

Nature-based Solutions' Contributions to Deep Resilience

Nature-based solutions are particularly important for resilience strategies in three ways: 1) they can complement gray infrastructure to create solutions that incorporate multiple resilience strategies, 2) they are multi-functional and particularly suited to integrated solutions, and 3) they can address maladaptive aspects or negative impacts of traditional gray approaches.

By complementing gray infrastructure, NBS are particularly good for balancing robustness and flexibility. For example, combining natural and engineered water storage solutions to withstand times of scarcity will enhance adaptive capacity in the face of change. Traditional surface water storage reservoirs, when used along with protecting the high-elevation paramos in the Andes that are a major source of groundwater recharge, and/or restoring ancestral nature-based managed aquifer recharge technologies that enhance groundwater storage means water sources can be adjusted in response to changing rainfall patterns.[11] Relying on either NBS or gray infrastructure alone is not likely to be a successful adaptation strategy and, importantly, reliance only on expensive, long-lasting, and inflexible gray infrastructure solutions can make adopting NBS in the future more difficult or expensive.[12]

In many cases, NBS can be more cost-effective alternatives with significant co-benefits that lend themselves to systemic solutions. For example, protecting source watershed forests and wetlands to maintain water quality for drinking water supplies can save costs by avoiding expensive (and energy intensive) treatment plants. At the same time, these forests and wetlands can provide a suite of co-benefits, such as sequestering carbon, moderating local climates, providing some protection from flooding and landslides, and supporting local economies through recreation, sustainable timber, or non-timber forest products.

Finally, in contexts where gray infrastructure solutions are not possible or have already resulted in maladaptation, NBS may be the only adaptation option. For years the city of New Orleans relied on flood control levees to manage riverine and coastal flooding from large storms, but during Hurricane Katrina, the levees held floodwaters in, causing additional damage. Relocating levees and restoring coastal marshes are providing more protection to New Orleans, while addressing some of the negative impacts of the original levee system, restoring carbon-sequestration in coastal wetlands, and enhancing fisheries production and economies.[13]

Adaptation Services from Nature and Nature's Adaptive Capacity

The ability of societies to thrive, especially under change, is dependent on the delivery of ecosystem services, which underpin all aspects of human well-being. The term "adaptation services" has been used to describe the "benefits to people from the capacity of nature to moderate and adjust to variable conditions, including some climate changes, and continue to provide the ecosystem services that underpin social resilience."[14] Adaptation services therefore include the ability of ecosystems to provide buffering against change (resistance), as well as the ability of ecosystems to recover from change through adapting and transforming. Buffering capacity

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[11] Recent research in the Peruvian Andes has documented the contribution of pre-Incan ancestral amunas for recharging groundwater and improving the resilience of local water supplies in the face of variable rainfall; Ochoa-Tocachi, B.F., Bardales, J.D., Antiporta, J. et al. 2019. "Potential contributions of pre-Inca infiltration infrastructure to Andean water security." *Nature Sustainability*. 2, 584–593. doi:10.1038/s41893-019-0307-1.

[12] In their examination of the history of the series of adjustments over 700 years in the face of changing water risks in Mexico City, Tellman and colleagues show how early gray infrastructure decisions required ever larger gray infrastructure interventions and cutting off other options for managing flooding and water supplies; Tellman, B., Bausch, J.C., Eakin, H. et al. 2018. "Adaptive pathways and coupled infrastructure: seven centuries of adaptation to water risk and the production of vulnerability in Mexico City." *Ecology and Society*. 23(1): 1. doi: 10.5751/ES-09712-230101.

[13] See for example: J.W. Day. 2007. "Restoration of the Mississippi Delta: lessons from hurricanes Katrina and Rita." *Science*. 315: 1679-84. doi: 10.1126/science.1137030.

[14] Lavorel, S. et al. 2015. "Ecological mechanisms underpinning climate adaptation services." *Global Change Biology*. 21, 12 – 31, doi: 10.1111/gcb.12689.

in the face of change helps ensure that the current suite of ecosystem services that are providing benefits to people will continue to be delivered, including services that may not be valued now but provide insurance or option values in the future.

The option value of ecosystems and well-designed NBS are some of the most important contributions of NBS to resilience. Many ecosystem services that are not highly valued now may become critically important under new climate conditions. For example, urban trees that deliver local climate regulation services in cities – shade from trees canopies, moderating air and water temperatures and maintaining soil moisture – may be considered amenities now but will become much more important in providing resilience to more frequent heat waves under warmer temperature regimes. The full suite of ecosystem services provided by NBS, even those not currently of obvious value, are the basis for maintaining flexible, open adaptation pathways for the future.

Adaptive Capacity of Nature-based Solutions

Carefully designed NBS not only provide adaptation services that contribute to individual and community resilience but can also adjust in the face of change to ensure the future delivery of those services. Incorporating diversity and redundancy in NBS provides traits that contribute to persistence, flexibility, and adaptive capacity. For example, forests with a diversity of trees with a range of drought tolerances are better able to persist in the face of drought, although there are limits to persistence when droughts are extremely deep or long. This means that in the face of at least some disruptions, biodiverse NBS can continue to provide the ecosystem services that contribute to individual and community resilience, such as climate mitigation, local climate regulation, improving water quality, or providing non-timber forest products.

Nature-based solutions will not be immune to the impacts of climate change, especially more extreme shocks, such as mega-droughts or drastic changes in monsoonal rainfall patterns. However, NBS designed to most closely mimic aspects that make ecosystems resilient also have some capacity to adapt and transform as conditions change. Transformations under extreme disruptions will result in new suites of ecosystem services that provide a different set of benefits to people. For example, permanent wetlands that provide little flood mitigation under current conditions may transform to intermittent wetlands under drier future conditions. Water quality benefits may be impacted given reduced capacity for nutrient and sediment retention; but because intermittent wetlands are not continually saturated, they have the capacity to absorb more runoff and provide new benefits in terms of some flood mitigation. Understanding how ecosystems may transform under climate change can provide clues for choosing which NBS to implement to enhance resilience as conditions change.

Limitations of Nature-based Solutions for Resilience

Even under current climate conditions, there are limitations to the kinds of disruptions NBS alone can effectively address. Nature-based solutions can be quite effective at protecting against moderate events but not as effective against extreme events. For example, forests that enhance infiltration of rainfall can reduce runoff and flooding following moderate precipitation events but not under more extreme, intense rainfall. Rapid and extreme climate disruptions may therefore overwhelm the ability of NBS for adaptation or positive transformation in the face of change. The effectiveness of NBS may also decline over time with climate change. Nature-based solutions incorporating more diverse plant communities can resist and recover from droughts more quickly than monocultures or species poor communities. But plant diversity is likely to decline in much of the world under warmer, drier conditions and more frequent droughts, potentially impacting the effectiveness of NBS designed for resilience to droughts.[15] Nature-based solutions need to be carefully designed to consider how climate change (and other stressors) may impact their functionality and resilience.

As noted above, under climate change, new disturbance regimes are likely to be radically different from those under which ecosystems have evolved. Examples include more frequent and intense wildfires in forests in the western United States, frequent episodes of coral bleaching in the Great Barrier Reef, and deeper droughts in the Amazon Basin. Rather than recover to some prior state, these ecosystems may be transforming into new states – novel ecosystems characterized by new sets of species and a new suite of ecosystem services. Abrupt changes are leading to tipping points or rapid shifts into new systems (e.g., forest shifting to savanna or grassland). While there is much uncertainty about the trajectory of individual NBS under climate change, designs that explicitly include steps to protect existing biodiversity or enhance biodiversity in restored or managed systems are more likely to continue providing adaptation services as the climate changes.

Nature-based Solutions and Transformative, Deep Resilience Strategies

Deep uncertainty and the inevitability of transformative disruptions call for deep resilience, in which NBS can support positive, systemic transformations to cope with climate change. Nature-based solutions alone will not result in deep resilience, but as critical assets, NBS can help enable the kinds of transformations that are needed in economies, energy systems, food and agriculture, water management, and human health.

To ensure deep resilience, integrated approaches that combine gray infrastructure and NBS are particularly strong, cross-sectoral solutions for addressing immediate changes and keeping options open for future adjustments. China's sponge cities are examples of resilience strategies to transform the urban fabric to prepare for increasingly intense rainfall and flooding, but also to address the myriad social issues impacting China's mega-cities. Planners are looking systemically across the multiple challenges facing China's rapidly growing and extremely dense cities, rather than addressing challenges individually. This approach is creating new kinds of cities with improved resilience across multiple, interlocking dimensions. Removing impervious surfaces, restoring large areas of interconnected wetlands and waterways, creating green open spaces, green streets, porous pavements, and improving traditional gray stormwater drainage not only allows these cities to cope with future flooding but also provides cooling spaces for coping with heat waves, water purification, and groundwater recharge to improve water security, water quality, and recreational

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[15] For discussion of how more diverse plant communities resist and recover more quickly from droughts and expectations that plant diversity is likely to decline in many parts of the world under drier, warmer climate see: Chapin, S. and Diaz, S. 2020. "Interactions between changing climate and biodiversity: Shaping humanity's future." *PNAS*. 117(12): 6295 – 6296. doi: 10.1073/pnas.2001686117; and Harrison, S., Spasojevic, M. J., and LiD. 2020. "Climate and plant community diversity in space and time." *PNAS*. 117, 4464–4470. doi: 10.1073/pnas.1921724117.

and natural areas that enhance the physical and mental health of residents. With this transformation, cities are positioned to thrive under the new climate conditions, and future resilience strategies in the reorganized cities may rely more on persistence and adaptation (see Figure 1).

In addition to climate change, Peru faces many intersecting and uncertain challenges in its dry coastal watersheds, including seasonal water scarcity, disappearing glaciers, loss of critical ecosystems, such as high-altitude grasslands and wetlands, rural poverty, a rapidly growing, young population, and economic inequality. In 2017, the Peruvian coast was hit by a series of severe floods and landslides caused by the *El Niño Costero* phenomenon. The disasters wrought billions of dollars of damage and hundreds of casualties. In response, Peru created a systematic program to "build back better": *Reconstrucción Con Cambios* (RCC). As part of an integrated strategy to build climate resilience – specifically, by managing risks of floods and landslides associated with climatic extremes – this program includes unprecedented investments in nature. Peru has developed a portfolio of over 200 million USD in investments in reforestation, shrubland and grassland restoration, and improved soil and water management practices to be implemented in the next four years. The investments, which are expected to restore over 50,000 hectares of critical landscapes in Peru's vulnerable coastal watersheds, are designed to protect soils from erosion and increase infiltration, reducing the risks of floods and landslides to vulnerable populations and critical infrastructure. At the same time, these investments will create rural jobs, protect farmers' livelihoods, and improve the resilience of critical water supplies. Rather than focusing on a single sector or individual problem, RCC is seeking convergent solutions to a set of interlocking issues of water insecurity, watershed degradation, rural poverty, economic inequality, and increasing climate hazards.

What does deep resilience mean for Nature-based Solutions in the NDCs?

While climate change and other anthropogenic stressors will influence how effective NBS will be, there are ways that NDCs must be strengthened through the inclusion of NBS to address these challenges:

1. Protect existing natural systems, especially those that are intact and healthy, as these are almost certainly providing adaptation services and should be core elements of NDCs and National Adaptation Plans.
2. Integrate hard, soft, and nature-based coping measures in diverse portfolios that are most likely to result in solutions that combine aspects of robustness and flexibility.
3. Anticipate, to the extent possible, how interacting stressors and shocks may affect the performance and viability of the NBS portfolios over time.
4. Design NBS for resilience that also deliver significant climate mitigation benefits by sequestering carbon in plants and soils.
5. Avoid NBS that may be unambiguously maladaptive (e.g., non-native tree plantations and afforestation that can negatively affect water yield and resilience to future climate change).

6. Embrace the likely need for some form of on-going management (adaptive management) of NBS that also monitors aspects of resilience and can guide when strategies need to shift direction.[16]
7. Avoid climate traps by leveraging the option value of nature to maintain the continued delivery of services in the face of change, including services which may not currently be valued but may be in the future.
8. Restoration should probably emphasize the restoration of function rather than historic ecological communities. For example, focusing more on the functions associated with the natural flow regime (in rivers) or the fire regime (in forests and grasslands) rather than species composition from decades or centuries past.
9. Mindfully prepare interlocking and systemic solutions: NBS are multi-functional, delivering multiple benefits simultaneously, meaning that they are ideally suited for taking a systemic view of problems and crafting systemic solutions.

Resilience strategies themselves will need to be flexible, considering both uncertainties and near-term disruptions and how these may change in the future (see Figure 1, Figure 2, and Figure 3). Deep resilience thinking and maintaining flexibility and transformative capacity through approaches such as NBS will be critical to coping with climate challenges and continuing to thrive under deep uncertainty.

[16] For a discussion and example of managing for resilience in freshwater systems, see: Grantham, T.E., Matthews, J.H., and Bledsoe, B.P. 2021. Managing freshwater ecosystems for ecological resilience in a changing climate. Water Security. 8:100049. World Bank. openknowledge.worldbank.org/handle/10986/35039.