Natural Climate Solutions

Handbook

A Technical Guide for Assessing Nature-Based Mitigation Opportunities in Countries

The Nature Conservancy

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Second Edition

This guide is available in Bahasa Indonesia, English, French, Mandarin Chinese, Portuguese, Spanish, and Swahili.

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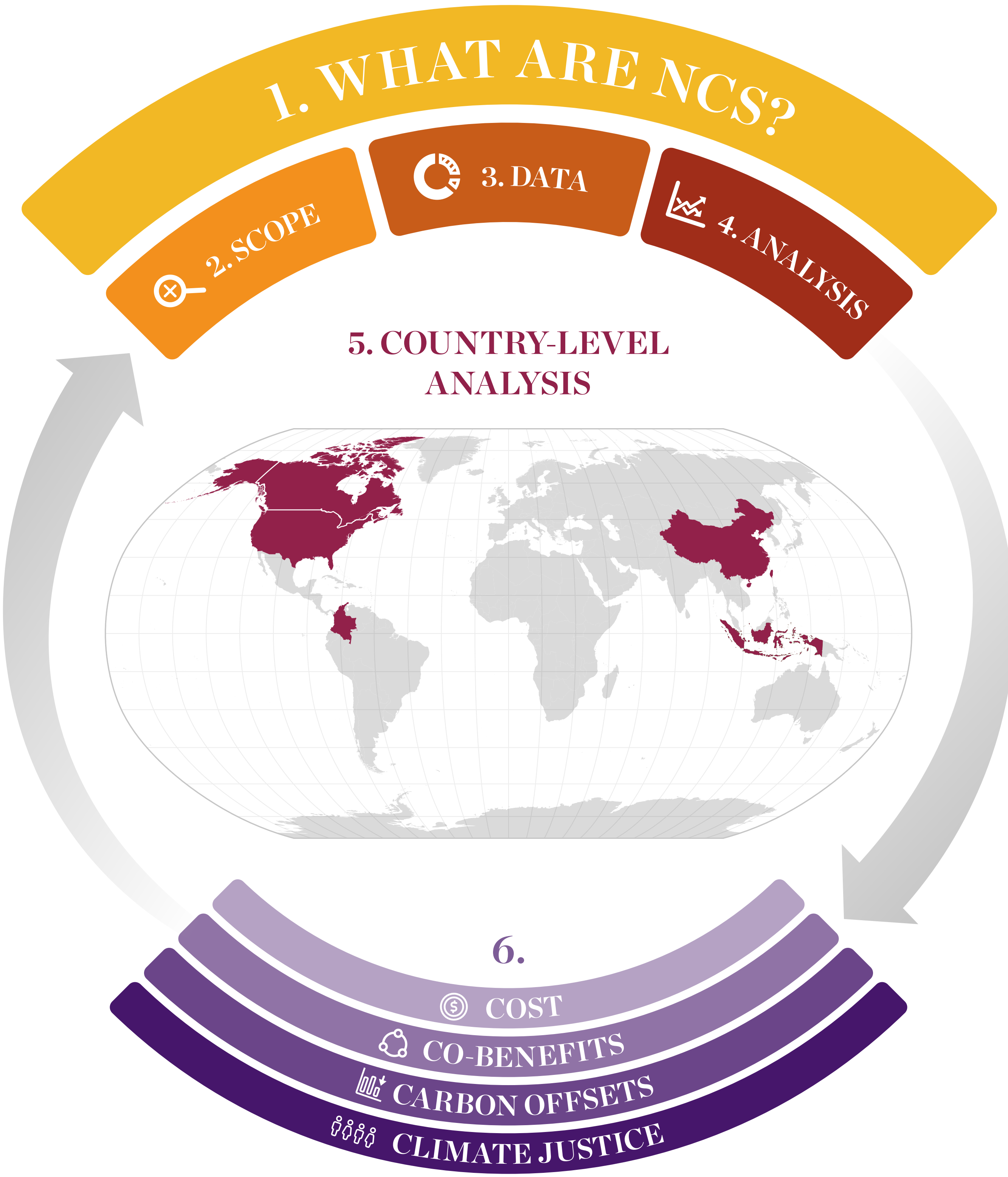

Figure 1: Graphical table of contents showing process flow

Acronyms and Units Related to NCS

COMMON ACRONYMS

AFOLU	Agriculture, Forestry, and Other Land Use
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land-Use Change and Forestry
NbS	Nature-based Solutions*
NCS	Natural Climate Solutions*
NDC	Nationally Determined Contributions*
REDD+	Reducing Emission from Deforestation and Forest Degradation*
UNFCCC	United Nations Framework Convention on Climate Change

**defined in Glossary*

Common Units with Abbreviations and Conversions

ha = 1 hectare	= 10,000m^2 = area of a square with 100-meter sides
Mha = 1 million hectares	
km^2 = 1 square kilometer	= 100 ha = area of a square with 1,000-meter sides
t = 1 metric ton (tonne) = 1.102 short tons (US) = 0.984 long tons (UK)	Mg = 1 Megagram (10^6 g)
Mt = 1 Megaton = 1 million tonnes	Tg = 1 Teragram (10^{12} g)
Gt = 1 Gigaton = 1 billion tonnes	Pg = 1 Petagram (10^{15} g)

RELEVANT GREENHOUSE GASES

C and CO_2 Carbon (C) is one of the most abundant elements on earth and the foundation for all living things. Carbon dioxide (CO_2) is a molecule consisting of one carbon and two oxygen atoms. CO_2 from the air is absorbed by plants and stored via photosynthesis in the form of carbon. In the atmosphere it is an abundant and long-lived GHG, emitted primarily through burning fossil fuels, as well as by land sector activities resulting in burning or decomposition of organic matter.

CO_2e For ease of comparison, GHGs other than CO_2 are translated to their carbon dioxide equivalents based on their varying global warming potential *(see Glossary). See "Converting GHG to CO_2e" on page 36 for conversions.*

CH_4 Methane, a potent GHG emitted from industrial activities, waste management, livestock, and natural systems such as wetlands.

N_2O Nitrous oxide, a potent GHG emitted primarily from industrial activities and agricultural practices such as fertilizer use.

NOx Nitrogen oxides, a generic term which includes nitrogen-based indirect GHGs nitrogen dioxide (NO_2) and nitric oxide (NO), emitted primarily through burning fossil fuels and biomass.

NH_3 Ammonia, emitted primarily from agricultural practices such as animal husbandry and fertilizer use, is an important short-lived pollutant which impacts nitrogen cycles.

1. What Are Natural Climate Solutions?

Scenic view in East Kalimantan, Indonesia. © Nick Hall/TNC

1.

Nature's Role in Achieving NDCs

The Paris Climate Agreement goals set in 2015 commit the international community to keep global warming well below 2°C and to pursue efforts to limit warming to 1.5°C[1].

To meet these goals, countries need to take action immediately to greatly reduce greenhouse gas (GHG) emissions and increase carbon sequestration and storage. To achieve this, we humans will need to take a closer look at how we treat the Earth and adjust our land use decisions to ensure we are taking advantage of mitigation opportunities in the land sector. Taking action at the scale required to avoid catastrophe is challenging, but it is both possible and necessary for the survival of many species and communities around the world.

A 2017 study led by The Nature Conservancy found that the land sector has the potential to deliver up to one third of the cost-effective mitigation needed by 2030 to hold global warming below 2°C, while supporting biodiversity and advancing the United Nations Sustainable Development Goals (SDGs)[2]. The authors called these mitigation strategies Natural Climate Solutions, or NCS for short. **NCS protect, manage, and restore natural and working systems in ways that avoid GHG emissions and/or increase carbon sequestration across forests, wetlands, grasslands, and agricultural lands**[2].

The nearly 200 countries who are a party to the Paris Agreement have made climate commitments known as Nationally Determined Contributions (NDCs). NDCs are updated periodically and are intended to increase in ambition in every cycle in order to gradually close the gap between business-as-usual emissions and the emissions reductions needed to maintain a stable climate. NCS strategies, or pathways, represent *additional* actions — that is, beyond baseline conditions — that countries can adopt to meet and exceed their climate commitments. **NCS are not a substitute for decarbonization of the energy sector; rather, they're a way to complement decarbonization efforts to help countries meet and exceed their emission reduction targets.**

Previous Page: Visiting mangroves on Lembongan Island, Indonesia. Mangrove forests support fishing jobs and food security. © Kevin Arnold/TNC

1.

NCS in NDCs

National climate targets and plans have improved dramatically since the Paris Agreement was adopted. When the first cycle of NDCs was submitted in 2015, many countries included language related to LULUCF, but only 70 (about a third) included quantified targets[3]. This gap indicated significant opportunity to increase the quantity and quality of NCS actions and targets in NDCs. By December 2020, 75 countries had submitted new or updated NDCs[4]. Of these, 48 countries provided quantitative mitigation targets for LULUCF. Examples of quantitative targets for LULUCF include:

- Level of absolute GHG emissions and removals for 2030.
- Relative GHG emission percentage reduction from business-as-usual level for 2030.
- Percentage of total land area of the country under forest cover for 2030.

While representation of NCS in NDCs is increasing, few countries have plans in place to harness the full cost-effective potential of NCS to deliver their NDCs. However, most countries cannot meet their climate goals without specific actions in the land sector.

Moreover, future NDCs will need to be much more ambitious. The recently published UNFCCC Synthesis Report[4] shows projected emission reductions of just 1% by 2030 compared to 2010 levels. The IPCC, by contrast, has indicated that emission reductions of around 45% are needed to reach the 1.5°C goal[5]. Meanwhile, as of July 2021, 131 countries which account for 73% of global GHG emissions, have adopted or are considering net-zero targets[6]. While targets continue to improve, warming under current policies is still projected to be well above 1.5˚C.

Dawn on the salt marsh at TNC's Lubberland Creek Preserve in Newmarket, New Hampshire, U.S. © Jerry and Marcy Monkman/EcoPhotography

The time to act is now. The potential for NCS to succeed is likely to decline after 2030 and drastically so after 2050[2]. The reasons for this are twofold: Climate change feedbacks will gradually reduce the resilience of ecosystems, in many cases reducing their ability to sequester and store carbon. Meanwhile, the relative impact of NCS will decrease if business-as-usual emissions continue to increase *(see Figure 2)*.

The global community has been setting climate change mitigation targets for decades — it's time to start fulfilling them. This guide will help by offering step-by-step instructions to those seeking to evaluate the potential of nature to mitigate climate change in their country or other jurisdiction.

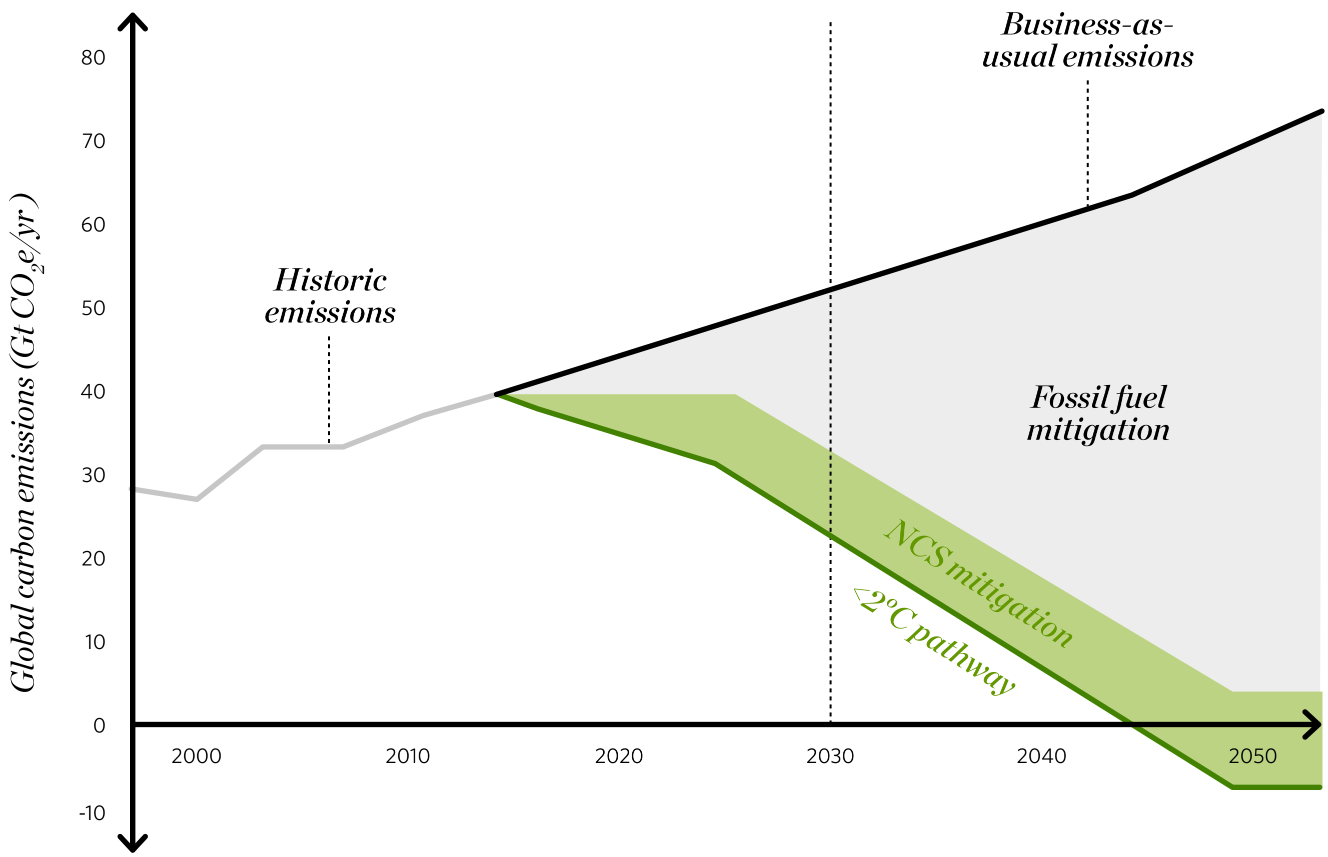

Figure 2: Natural climate solutions contribution to stabilizing warming below 2°C[2]

1.

About This Guide

An NCS analysis will help identify what land management actions have the greatest mitigation potential at any scale and in any landscape. The Nature Conservancy and partners have conducted a range of NCS analyses across the globe over the last 5 years. We developed this guide so that we could share the hard-won lessons learned by the scientists and conservation practitioners who have tackled these analyses. We've dug deep into the scientific literature, as well as our collective experiences, to gather as many best practices as possible for this guide in order to support a range of technical audiences and decision makers in scoping and conducting an NCS assessment.

In this guide, we **outline basic parameters for getting started with an NCS assessment, flag key decision points, and explain the factors to consider when making those decisions** for your unique situation. This guide is structured to match the order of steps we generally follow when conducting an NCS assessment—from identifying purpose and audience, to prioritizing and defining locally relevant pathways, to identifying the extent of opportunity and relevant GHG fluxes for each pathway, to estimating mitigation potential and costs – noting that many of the steps are iterative, requiring refinement after another step has been conducted. We've shared guidelines and best practices for navigating these complexities and accurately assessing the nature-based climate mitigation potential in your country or jurisdiction. Whether you're starting from scratch or already on your way, we've designed this guide so that you can jump into any section as your starting point. Our goal is to provide each reader with the tools they need to make the decisions that are most appropriate for their unique case.

We also share in this guide brief **case studies** from Canada, China, Colombia, Indonesia, and the United States (U.S.) that demonstrate how teams have adapted the global NCS framework to their needs, including the lessons learned in the process. **Appendices** provide a range of additional resources and allow you to dig deeper into some of the factors needed to realize NCS opportunities. In this guide we reflect on how to consider impacts on people and biodiversity, and how to ensure that NCS actions benefit, rather than harm, local communities.

This guide is a complement to the Guide to Including Nature in Nationally Determined Contributions, which provides a concise summary of the technical resources available to countries as they consider how they might incorporate NCS into their NDCs, and is available in English, Spanish, French, and Portuguese.

Our intention is that this guide will be easy to use and will outline a clear pathway to assessing NCS opportunity at any scale.

2030 is fast approaching, and every feasible path to addressing climate change includes NCS. It's time to shift from words to numbers and focus on action. It's essential, and it's doable. Let's get started.

1.

NCS Principles

Careful accounting: At its core, the NCS concept is an accounting framework, carefully structured to comprehensively evaluate nature-based mitigation potential while avoiding double counting.

Do no harm: This framework takes a "do no harm" approach, with particular emphasis on safeguards to protect biodiversity and maintain food and fiber production for people. NCS only include activities considered to have either a neutral or positive effect on biodiversity, and is aligned with the "nature positive" principle endorsed by many public, private sector, and civil society leaders[7].

Cost-effective: Carbon pricing, implementation costs, costs of alternate mitigation or adaptation options, and other factors will impact the scale of mitigation potential available from NCS. Some pathways are relatively expensive to implement, while implementation of others may achieve cost savings. In many cases, NCS offer cost-effective climate change mitigation *(see "Characterizing Costs" on page 41 and Appendix: Cost Estimates).*

Co-benefits: In addition, NCS activities often confer valuable co-benefits that may motivate implementation, such as improving air quality, improving water quality and regulation, enriching soil, supporting biodiversity, and improving ecosystem resilience and ability to adapt to future climate change *(see Appendix: Co-Benefits).*

NCS are not a substitute for reductions in fossil fuel emissions: However, in some cases, they can be used to "offset" unavoidable emissions *(see Appendix: Carbon Offsets).*

Climate Justice: In order to do no harm, special care should always be taken to understand the context and consequences of NCS implementation on different groups. Project planners should carefully consider who benefits from protection, management, or restoration activities, as well as who is at the table throughout the process. Ideally, NCS can help begin to correct historic environmental injustices and reduce inequalities. However, if not properly structured, they may worsen equity gaps *(see Appendix: Climate Justice).*

Natural Climate Solutions or Nature-based Solutions?

Natural climate solutions are a subset of Nature-based Solutions (NbS). NbS address societal challenges and SDGs while providing human well-being and biodiversity benefits. They include many services provided by nature (e.g., climate change mitigation, ecosystem resilience and adaptation, green infrastructure, and ecosystem services)[8,9]. The term NCS is used throughout this guide to refer to our specific GHG accounting framework for nature-based climate mitigation. For countries already working on NbS more broadly, framing communications using the term NbS can pave the way toward understanding and acceptance of NCS as a key climate action.

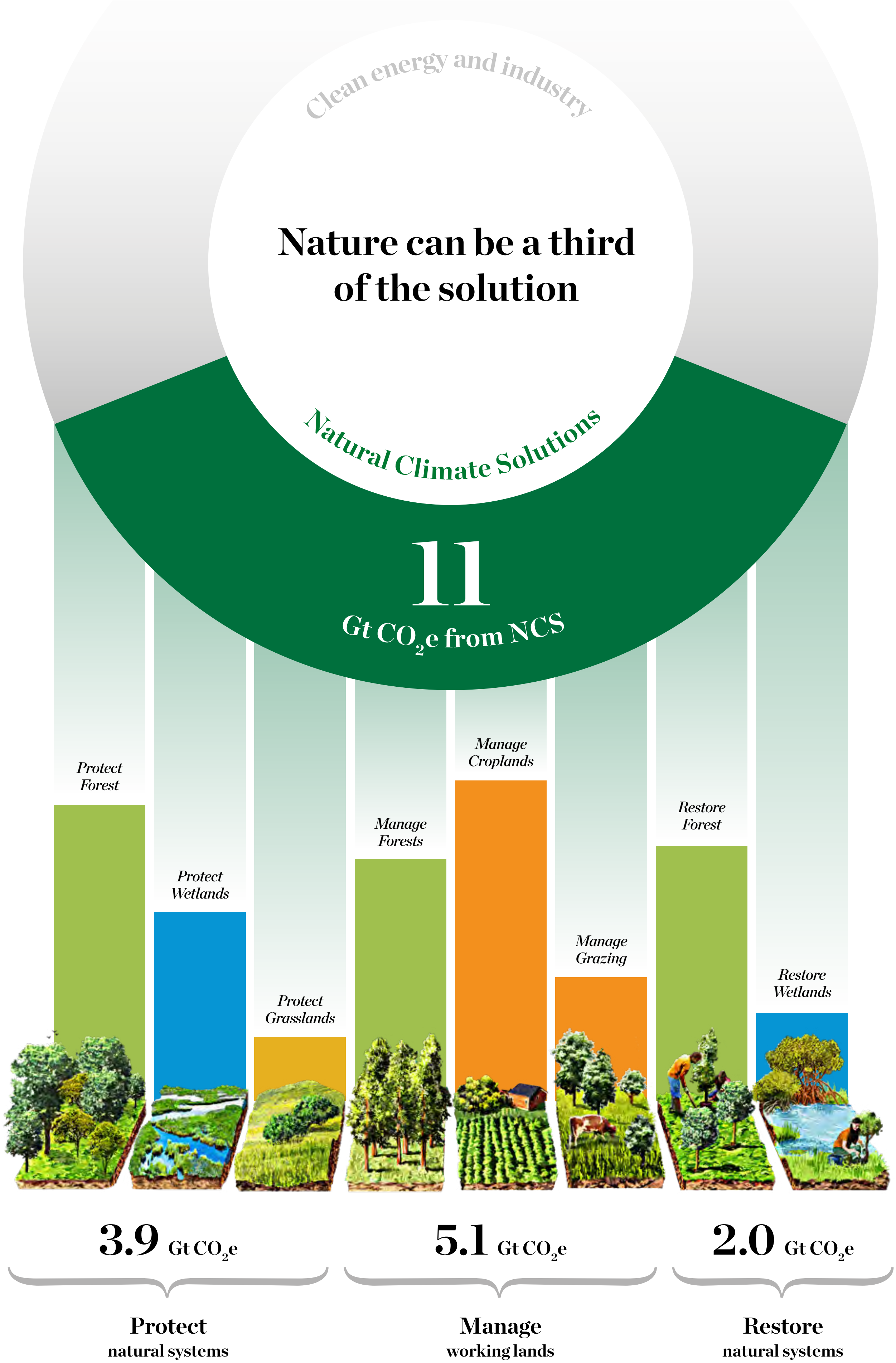

Figure 3: Cost-effective levels of NCS implementation can provide a third of the solution to meeting Paris Agreement goals

Visiting mangroves on Lembongan Island, Indonesia. Mangroves support fishing jobs and food security and can strengthen the resilience of coastal communities to storms and sea level rise. © Kevin Arnold/TNC

NCS Pathways

Natural climate solutions fall into three main categories: **protection** of natural systems, improved **management** practices on working lands, and **restoration** of native cover. These can be further divided into "pathways" that increase carbon sequestration and storage and/or avoid GHG emissions across **forests**, **wetlands**, **grasslands**, and **agricultural lands**. *Also see Table S2 from Griscom et al. 2017, Supplemental Methods from Fargione et al. 2018, and Box 1 of Drever et al. 2021 for detailed definitions.*

FOREST PATHWAYS

Forests can include any land dominated by trees, including tropical rainforests, dry forests, boreal forests, woodlands, and tree plantations. Both soil and biomass CO_2 fluxes and carbon pools are considered[10]. *See "When is a forest a forest?" on page 33.*

Avoided Forest Conversion. Avoided emissions from preventing human conversion of forest to non-forest land uses such as agricultural, urban, or industrial lands. (Note, temporary changes in forest cover from harvest should be considered in the *natural forest management* pathway.)

Climate Smart Forestry. Avoided emissions and/or increased sequestration in working forests. Potential management activities could include reduced-impact logging practices, deferred harvest (an intentional reduction in forest harvesting intensity, including cessation of logging on some parcels), enhanced forest regeneration in post-harvest stands and other actions.

Forest Plantation Management. Increased sequestration in forest stands through strategies such as extending rotation length (time between harvest cycles) in even-aged, intensively managed plantations. Some NCS analyses have also considered carbon stored in wood products.

Forest Fire Management. Avoided emissions in fire-prone forests and savannas through management practices such as prescribed burning to reduce the risk of high-intensity wildfire or shifting timing of burns to reduce GHG emissions. In wetter forests where fires are less frequent, implementing fire control practices along forest edges to avoid human-caused fires.

Avoided Woodfuel Harvest. Avoided emissions due to reduced harvest of wood used as fuel for cooking and heating, primarily through use of more efficient cookstoves.

Urban Canopy Cover. Increased sequestration by increasing tree canopy in urban areas, and/or maintaining carbon storage by preventing trees from being lost and replacing those that die.

Reforestation. Increased sequestration from restoration of forest cover, that is, transitioning non-forest land uses to forest land uses in places where forests historically occurred.

WETLAND PATHWAYS

Wetlands include freshwater systems, such as peatlands and freshwater mineral wetlands, as well as marine or "blue carbon" systems, such as mangroves, salt marshes, and seagrass meadows. Both soil and biomass GHG fluxes (including CO_2, CH_4, and N_2O) and carbon pools are considered[11]; to avoid double counting we have usually categorized mangroves, forested peatlands, and other forested wetlands as wetland pathways.

Avoided Coastal Wetland Impacts. Avoided emissions by preventing degradation and/or loss of saltwater wetlands (including mangroves, salt marshes, and seagrass beds) from drainage, dredging, eutrophication, or other anthropogenic disturbances.

Avoided Freshwater Wetland Impacts. Avoided emissions by preventing degradation and/or loss of freshwater wetlands (primarily peatlands) from peat fires, drainage, dredging, eutrophication from fertilizers, or other anthropogenic disturbances.

Coastal Wetland Restoration. Avoided emissions by restoring degraded saltwater wetlands (including mangroves, salt marshes, and seagrass beds) through activities such as rewetting or increasing salinity by reestablishing hydrologic connectivity, as well as increased sequestration by restoring vegetation.

Freshwater Wetland Restoration. Avoided emissions from degraded hydric soils by restoring the hydrologic function of drained or converted freshwater wetlands (primarily peatlands)[12] and increased sequestration by restoring vegetation.

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GRASSLAND PATHWAYS

Grasslands include prairies, steppes, shrublands, tundra, savannas, and other natural habitats with little or no tree cover. CO_2 fluxes are considered, and soil is the primary carbon pool.

Avoided Grassland Conversion. Avoided emissions by preventing conversion of native or managed grasslands and shrublands to cropland.

Grassland Restoration. Increased sequestration from restoring cropland to grasslands areas with limitations on agricultural production, grassland or shrubland in places where those systems historically occurred.

The Bluebell Ranch in South Dakota sits within the Prairie Coteau landscape, which is one of the largest remaining grasslands in the U.S. © Richard Hamilton/TNC

AGRICULTURAL PATHWAYS

Agricultural lands include any lands extensively managed for crops or livestock, including agricultural fields, pastures, and other grazed areas. GHG fluxes include CO_2, CH_4, and N_2O. Soil is the primary carbon pool.

Trees in Agricultural Lands. Increased carbon storage from adding or protecting trees in crop or pasture lands. This could include silvopasture (trees in grazing lands), tree intercropping/alley cropping (trees in rows with annual crops in between), riparian buffers, shelterbelts/windbreaks, and/or farmer-managed natural regeneration (changing management to allow trees to naturally regrow in some areas).

Rice Management. Avoided emissions through improved practices in flooded rice cultivation, including mid-season drainage, alternating wet and dry cycles, and/or removing residues.

Nutrient Management. Avoided emissions from fertilizer manufacture by reducing the over-application of nitrogen fertilizer through adoption of the "4R" best practices (right source, right rate, right time, and right place)[13].

Biochar. Increased sequestration in agricultural soils by converting crop residues to charcoal and applying these as soil amendments to agricultural fields. This pathway does not include forest residues to avoid possible perverse incentives that may inadvertently reduce carbon stored in forests.

Cover Crops. Increased sequestration in agricultural soils from growing additional crops when the main crop is not growing. When legume crops are used, decreased emissions from fertilizer manufacturing resulting from reduction in use of inorganic fertilizer are also included.

Reduced Tillage. Increased sequestration in agricultural soils by adopting reduced- or no-till practices in croplands.

Legume Crops. Avoided emissions from reduced use of nitrogen fertilizers by switching cultivation from grains to legumes in alternating years.

Legumes in Pastures. Increased sequestration in soils due to sowing legumes in planted pastures; restricted to areas where this would result in net sequestration. Also includes, where relevant, avoided emissions from fertilizer application to pastures.

Grazing Optimization. Increased soil sequestration by increasing grazing in locations that are understocked and decreasing grazing in locations that are overstocked.

Grazing Animal and Feed Management. Avoided emissions due to reduced enteric fermentation in ruminant animal guts through 1) breeding and animal health techniques, or 2) the use of more energy-dense feeds such as cereal grains and improved pastures.

Manure Management. Avoided emissions from improved management of manure, primarily in handling facilities of dairy and hog operations.

2. Defining Scope

When beginning an assessment of how NCS can mitigate climate change in your country or jurisdiction, you'll first need to consider the scope. This section provides suggestions for how to determine the audience, scale, and content of the assessment. Defining and refining scope will take longer than you think — ensure adequate time for this step!

Identifying Purpose and Audience

The first step for any NCS mitigation potential analysis is to identify its central purpose, such as defining a new national mitigation target or defining implementation strategies for meeting an existing target. You will also want to identify the target audience for your assessment, including those who can influence how your findings are acted upon.

Some good questions to consider before starting include:

- *Does your country's NDC, or other national or sub-national climate change mitigation goal, include natural and working lands? If so, does the goal have a numerical target and sufficient degree of detail to enable action?*
- *Are there existing frameworks for assessing NCS potential in your country, such as national inventory reports?*
- *Which, if any, government ministry or agency is tasked with setting climate policy and regulating climate action?*
- *What ministries and agencies influence agriculture and natural resource management?*
- *Are there civil society organizations, or corporate and civil society funders who will advocate for certain policies?*

The responses to these questions will help identify the purpose and audience and will also influence the scope and priorities for structuring your analysis.

Determining Scale

Once the primary purpose and target audience are identified, you can begin to decide how deep (for example, using global, national, or local data) and how broad (for example, type and number of pathways) the analysis should be. There may be several iterations of decision-making as each of these dimensions are refined during the remaining steps in Part 2.

Previous page: Tropical forests in East Kalimantan, Indonesia. © Nick Hall/TNC

HOW DEEP?

In some cases, a quick analysis using a global-scale resource such as the NCS World Atlas will be sufficient for your needs. Though coarse in resolution, **global data can be useful for getting a general sense of the opportunity** in a given place or for comparing opportunities worldwide.

In other cases, your purpose and target audience may necessitate a finer-scale assessment (i.e., at a country or sub-national level) that involves more stakeholders in the process. For instance, will your audience accept the conclusions if they haven't been involved with the assessment? Will meeting your goal require involvement of certain people or institutions at the beginning of the process? In some cases, global data may be sufficient from a scientific perspective, but would not be adequate to achieve your goals.

NCS World Atlas: A Tool for Quick Assessment

If quick numbers are needed to simply assess the magnitude of opportunity within a country or to compare across countries, visit the NCS World Atlas[14]. This Atlas has downloadable country reports and is regularly updated with estimates of NCS potential based on the latest and best available global science. These numbers are a great tool for starting a conversation with policy-makers, corporations, or multilateral organizations who are interested in learning more about the potential for NCS.

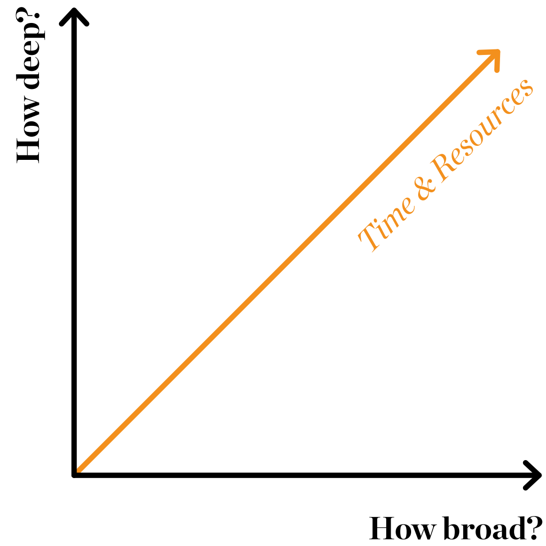


Figure 4: Balance depth and breadth of assessments for efficient use of time and resources

For most **implementation planning and policy decision-making, analyses will need to be done at a sub-national level.** Where available, finer-resolution data allow more precise estimates of where NCS opportunities are and how much mitigation they offer. Finer-scale analyses also allow for locally appropriate definitions and the opportunity to build in additional variables of local interest. For example, if a country has a specific policy related to trees along roadsides (e.g., India's Green Highways Mission), you might include an analysis of national road maps to refine your estimates of NCS opportunity.

HOW BROAD?

Once you've decided on the depth of your analysis, the next step is to determine whether you'll investigate all relevant NCS pathways or just a subset.

Evaluating each pathway takes time and resources, so it can be advantageous to narrow your focus: In our experience, conducting a full assessment of all pathways and publishing an accompanying report takes at least 18 months and requires inputs from a large team of researchers. In general, the best

Corn Fields outside of Arapahoe, North Carolina, U.S. at sunset © Will Conkwright/TNC

practice is to go only as deep and broad as is needed to accomplish your purpose. For instance, you may already know which pathways are policy priorities or have the greatest mitigation potential. Conducting a rapid mitigation analysis of a few key pathways that uses readily available data can also allow more time and resources for conducting follow-up economic, social, and policy analyses that can inform implementation.

On the other hand, when resources allow, a full NCS assessment can be worth the substantial investment and can yield surprising results. For example, in Canada, before conducting our full assessment we predicted that the forest sector would yield the highest mitigation potential. Instead, we found that by 2030, *avoided grassland conversion* represented the single largest pathway-level mitigation opportunity and that the agricultural sector overall had more opportunity than the forest sector[15]. This is due to the slow growth rate of trees, and the warming effect of tree cover in Canada (i.e., albedo, *see Glossary*), which means the forest sector will take more time to achieve its mitigation potential. Without a full NCS Canada assessment, we would not have uncovered this unexpected result. A full assessment can also help to build a science-based NCS community of practice, galvanizing experts from different fields who may not otherwise convene. In addition to building a network of relationships among stakeholders, this community of practice can provide a credible venue for exploring trade-offs among sectors.

It may not be clear at the beginning of the process whether or how to focus your analysis. It can be useful to start broad with your scoping research and narrow down to particular pathways as the analysis unfolds and more information becomes available.

Prioritizing Pathways

If you do choose to focus your analysis on a subset of pathways, but it's unclear which are likely to be the highest priority for your target audience, there are a number of factors to consider:

MITIGATION POTENTIAL

It is important to identify which pathways are likely to have significant mitigation potential in your location. Note that it may not be very feasible to achieve the maximum biophysical mitigation potential, so it may be helpful to consider how mitigation potential may vary at carbon price points of 10, 50, or 100 USD per metric ton of CO_2e (*see "Characterizing Costs"*). For example, at the global scale, *reforestation* has by far the highest biophysical maximum mitigation potential if costs are not considered, but at carbon prices up to 100 USD per ton, its potential is equivalent to the potential from *avoided forest conversion*. Understanding how the potential from different pathways varies by cost may influence the relative emphasis placed on each pathway — though you may not have clarity on this until considering costs later in the process.

LOCAL RELEVANCE

Understanding the local context is key for selecting or adding appropriate pathways. For example, *rice management* may have high or nonexistent potential depending on how much rice a country produces. National policies may also play a role. For instance, global data shows high mitigation potential for *avoided forest conversion* in China; however, permanent forest conversion should be low due to the launch of the Ecological Conservation Redline policy that seeks to protect more than a quarter of the Chinese mainland.

CO-BENEFITS

While NCS assessments focus on climate change mitigation, the activities considered can often have other benefits (*see Appendix: Co-Benefits*). You may want to prioritize pathways that offer co-benefits that are of interest to your target audience and other stakeholders.

COMMUNITY IMPACTS

Some pathways may have a greater likelihood than others of helping or harming local communities. For instance, some pathways may produce economic benefits such as cost savings for farmers implementing fertilizer management practices or sustainable fishing opportunities from mangrove restoration. You may want to prioritize pathways based on potential benefits to local communities. Be aware that attainment and equitable distribution of benefits relies on careful construction of the analysis and subsequent implementation.

INFORMATION AVAILABILITY

There may be pathways that have potentially high mitigation potential, but lack sufficient information to proceed. At that point, you will have to consider whether it is best to proceed with other pathways for which data is available, or whether this is an important data gap that could be filled with additional primary research – and if filling that data gap is in scope for your study.

MITIGATION HIERARCHY

It is important to reduce harm to the greatest extent possible before taking steps to counteract any remaining unavoidable harm. When applied to NCS, this concept means sequentially considering options to 1) drastically reduce GHG emissions from energy, industry, and transport sectors, 2) protect intact natural lands, 3) improve the management of working lands, and 4) restore degraded or converted natural lands.

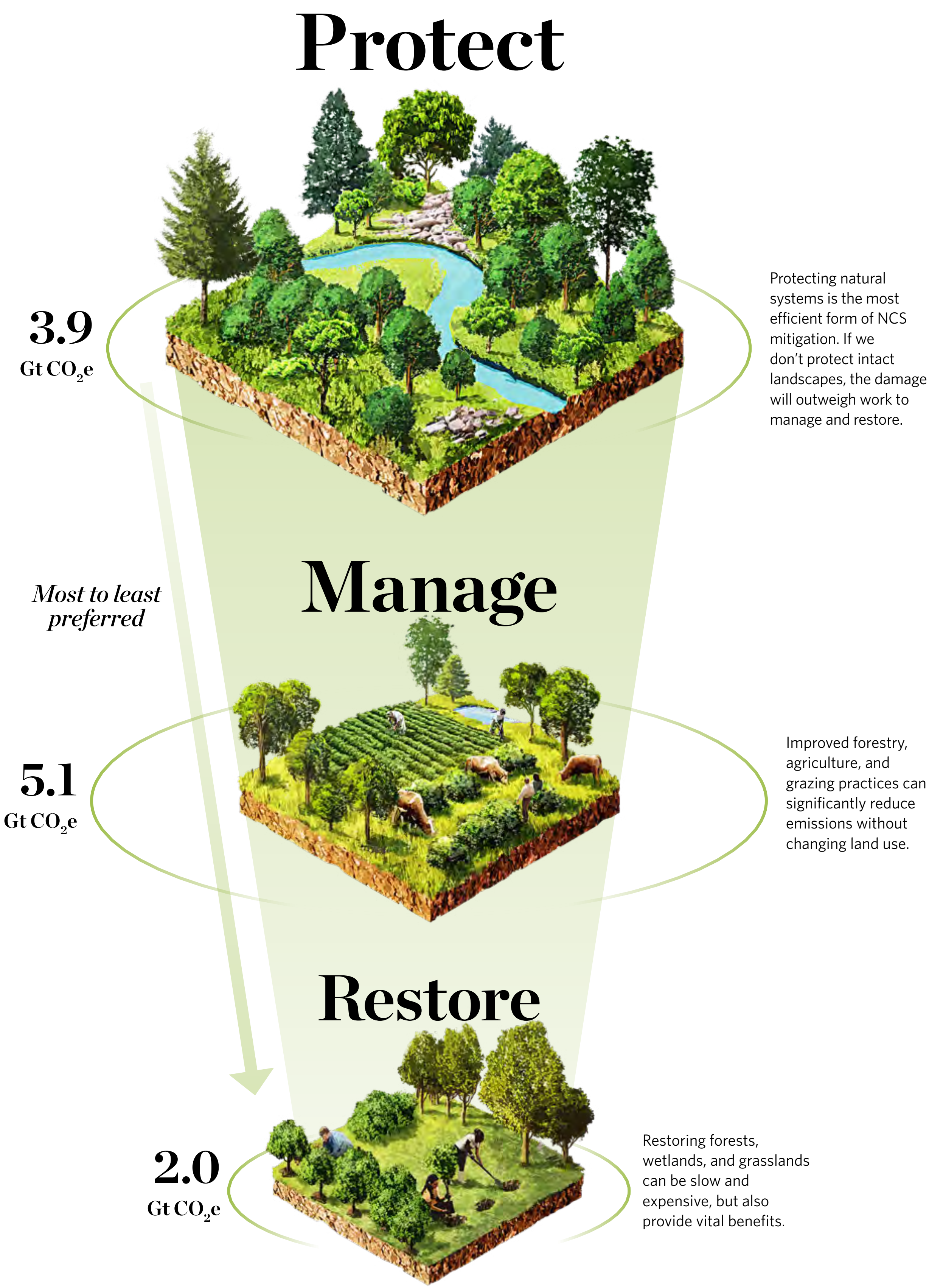


Figure 5: The mitigation hierarchy as applied to NCS emphasizes protecting intact systems

Peatland research area in Tanjung Putting National Park, Central Kalimantan, Indonesia. © Nanang Sujana/CIFOR

These actions can and should be deployed concurrently; the mitigation hierarchy simply places emphasis on reducing harm. It can also help optimize investments to ensure the highest possible mitigation will be achieved with the time and resources invested. For example, if your country is experiencing high rates of forest conversion, forest restoration may not be the best area to focus on if action is not also being taken to greatly reduce forest conversion as the conversion would undermine the restoration efforts.

SECTOR

It may streamline analytical and policy considerations to look comprehensively at a single sector, such as forestry or agriculture, or at trade-offs between two sectors, such as the impact of expanding agriculture on grassland conversion. Be careful, though, to acknowledge any interactions with sectors you choose not to directly include in the analysis.

SOCIAL OR POLICY RELEVANCE

Some pathways may be more or less feasible in a country depending on existing social or cultural factors and policy frameworks. For example, implementing *trees in agricultural lands* in Colombia aligns with social and cultural traditions. It may make the most sense to choose pathways that will be easier to implement or are already of interest to decision-makers. On the other hand, it may be possible to advocate for a pathway that has high mitigation potential but is seen as less politically viable or has simply been overlooked, such as soil carbon in mangrove systems in Indonesia, by including it in your analysis.

STAFF CAPACITY

While partners are critical for any NCS analysis, it may be most efficient to use in-house expertise to conduct the most time-consuming parts of the analysis and to manage the project, so it may be useful to focus on topics where your team already has experience. If recruiting or contracting outside expertise, it may be advantageous to seek out researchers who are highly influential in a given field. It is critical to include local researchers who will be most familiar with the activities under consideration and their potential social and ecological impacts. Involving early career researchers, such as student and postdoctoral researchers, can build needed capacity and support their own research and career goals.

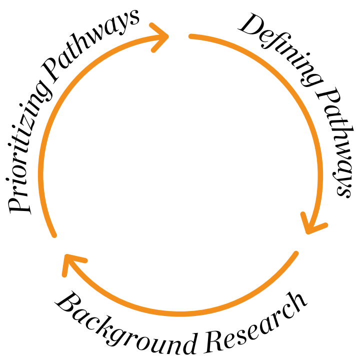
Caguan river landscape in the Colombian Amazon. © Diego Lizcano/TNC

2.

Defining Pathways

Ideally, you will select NCS pathways from the list in Part I (*see pages 14-17*). Consistency of NCS definitions across studies helps to advance NCS as a global movement and facilitate transparency and accountability across countries. However, in some cases, it may be necessary to add or adjust a pathway to better suit the local context. If you add or modify a pathway, be sure your changes are clearly defined and meet the following criteria.

Figure 6: Appropriately scoping an NCS assessment is an iterative process



An NCS pathway must:

- *Be measurable.*
- *Track additional mitigation opportunity beyond a baseline.*
- *Avoid double counting with other pathways (see "Determining Extent", page 32).*
- *Maintain food and fiber production.*
- *Avoid negative consequences to biodiversity and people.*

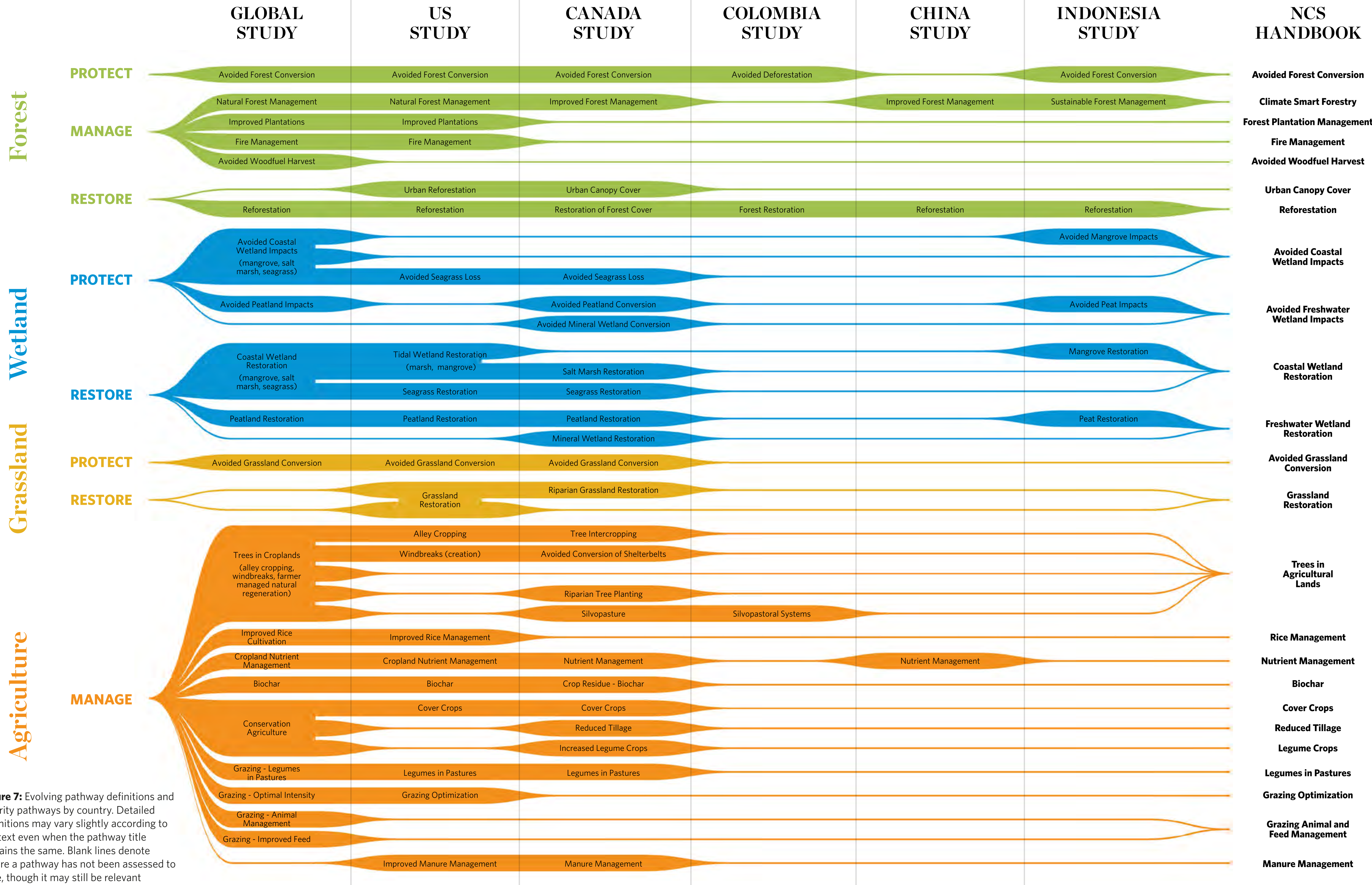


Figure 7: Evolving pathway definitions and priority pathways by country. Detailed definitions may vary slightly according to context even when the pathway title remains the same. Blank lines denote where a pathway has not been assessed to date, though it may still be relevant

Conducting Background Research

LITERATURE REVIEW

As with any research endeavor, starting with a literature review will identify the best-available information and avoid duplicating existing analyses. It can also help identify potential rightsholders and other stakeholders that need to be consulted. In addition to published academic literature, other sources of information may be useful, including: online data viewing portals; reports by governments, non-profits, and private sector entities; and national or sub-national greenhouse gas inventories, land use plans, and agricultural subsidy schemes. During this review, you might also identify a policy-relevant target year around which to structure the analysis (*see "Choosing a Time Horizon" page 39*).

PUBLIC POLICY REVIEW

Next, we recommend reviewing existing public policies in your location, examining the motivations, targets, metrics, and data sources that underlie the policies. Many countries already have NCS-relevant policies in place such as those aimed at reducing deforestation, promoting the restoration of natural ecosystems and degraded areas, or establishing a price on carbon that support actions to sequester or avoid CO_2 emissions[16]. These types of policies tend to be the outcome of joint efforts between legislators and other government agencies, which may increase the likelihood that an NCS action is implemented. If the information can be obtained, also consider sub-national policies and traditional and customary land use arrangements, especially those impacting Indigenous groups or marginalized communities.

Examples of national policy instruments to be considered include[16]:

- *NDC documents and National Communications to the UNFCCC*
- *Nationally Appropriate Mitigation Actions (NAMAs) to the UNFCCC[17]*
- *National climate change policies and laws*
- *REDD+ strategies[18]*
- *International commitments such as the Bonn Challenge and National Biodiversity Strategy and Action Plans (NBSAPs) to the United Nations Convention on Biological Diversity*
- *National Adaptation Plan (NAP)*
- *Regulations on carbon markets*
- *Low-carbon development strategies*
- *Land use planning approaches*
- *Protected area plans*

National Climate Policies Needed

As of 2018, 157 countries had set economy-wide emission reduction targets in their NDCs, but only 58 had codified those targets in national laws or policies, and only 17 had enacted national laws or policies directly consistent with the targets set in their NDCs[3]. This tells us there is clearly room to improve the coherence between domestic policies and international NDCs. The two have significant overlap in scope, and when aligned, can strengthen each other and deepen their collective impact. There are already signs that the new and updated NDC targets submitted in 2020 include improved data related to NCS, and are better integrating national and international policies[4].

EXPERT AND STAKEHOLDER MEETINGS

It is crucial to engage a diverse range of stakeholders and experts in the earliest phases of framing your NCS assessment[8]. Having conversations with these groups will allow you to identify their needs and existing strategic mitigation plans, as well as potential barriers and opportunities for NCS implementation. Stakeholders may include researchers from the public, private, non-profit, or academic sectors; policy experts and decision-makers; rightsholders such as representatives from Indigenous and other local communities; and youth advocates.

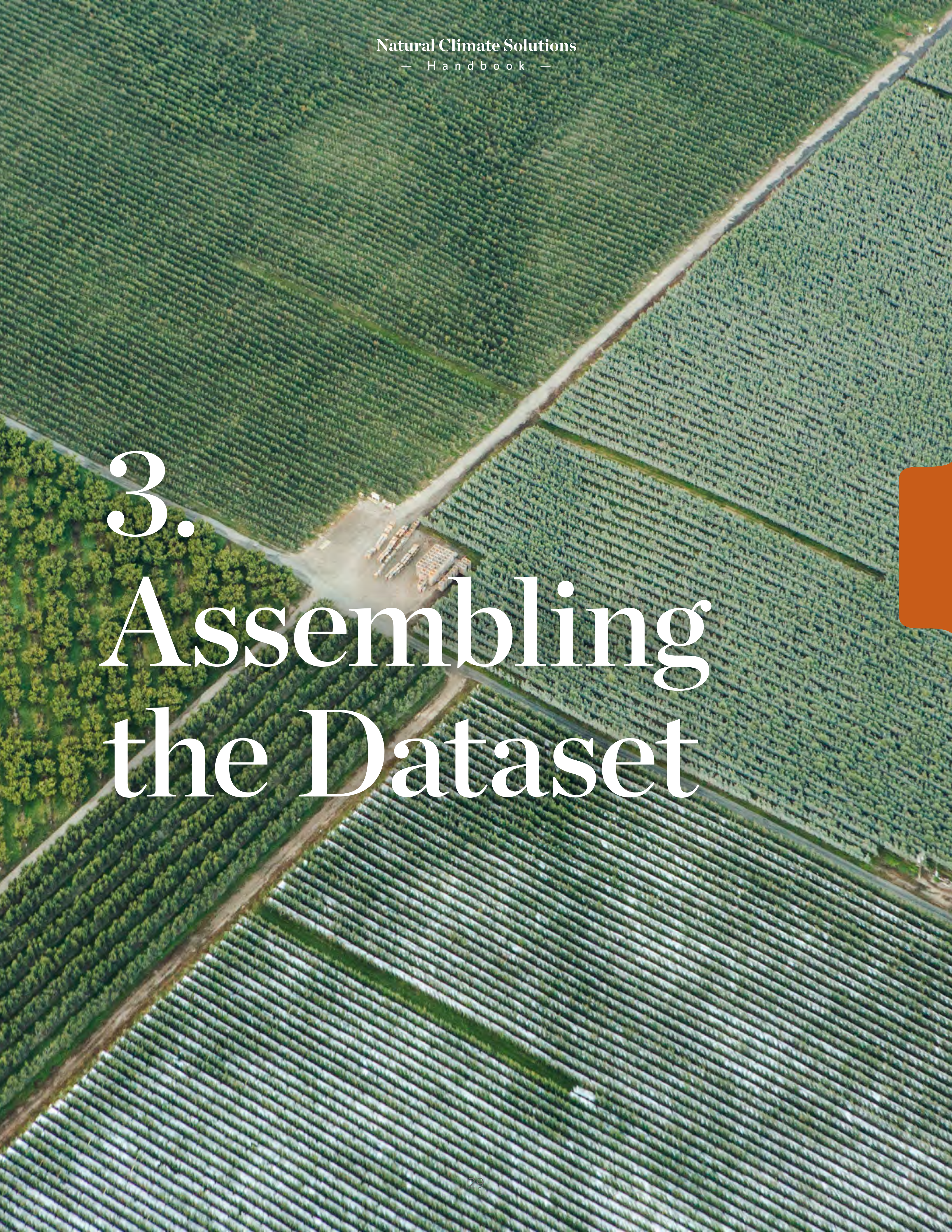
Within governments, a range of ministries or agencies may be responsible for actions related to NCS policy and implementation, including ministries of forests, natural resources, environment, climate change, agriculture, livestock, fisheries, economy, and/or finance; government sectors in charge of climate negotiations; and sub-national and local governments. Since ministerial coordination is needed to ensure NCS potential is achieved across sectors, it is important to invite involvement from a cross-section of government groups who might be responsible for NCS rollout to ensure that the analysis will have uptake by the target audience. Making connections with relevant government sectors can also allow for follow-up conversations on challenges encountered and progress made during NCS implementation[16].

Other groups will bring different perspectives. Private sector representatives may be most interested in investing in NCS to meet climate neutrality or sustainability goals or offset unavoidable emissions, while academic researchers may be more focused on identifying the best-available information and models for assessing NCS mitigation potential and co-benefits. Community advocates may be most interested in cultural, health, or livelihood co-benefits or in addressing historical inequities. It is important to engage with these diverse perspectives and keep in mind that decisions made when structuring the assessment may have implications in the real world that impact stakeholder groups in different ways. Policy-making processes are often challenging to navigate, especially for marginalized groups. By including a variety of stakeholder groups in the analytical process you can help ensure those perspectives are integrated into the findings shared with decision-makers.

Host an NCS Workshop

We have found that, after some initial planning and background research, it is very useful to hold a 2- or 3-day kick-off workshop. Meeting with 20–30 key representatives can help you gather additional information, discuss the decision points identified in this guide, and engage researchers to be involved in conducting the analysis. In addition to offering guidance, these experts and other stakeholders can also become champions for disseminating the resulting NCS analysis and implementing mitigation strategies.

For example, the team in Indonesia partnered with the research agency of the Ministry of Environment and Forestry to host a workshop to socialize the NCS concept and identify the top priority pathways for the national assessment. By including a large number of stakeholders in this process, the team achieved a high level of buy-in from influential parties, which was further strengthened by ongoing engagement after the workshop to ensure continued alignment.



3. Assembling the Dataset

3.

Powderhorn Ranch, one of the few remaining large tracts of intact native coastal prairie and wetlands on the Texas coast, U.S. © Jerod Foster/TNC

Once you have identified pathways for analysis and are familiar with the relevant existing research, policies, and stakeholders, the next step is to compile the datasets necessary to calculate the mitigation potential of each NCS pathway.

When searching for datasets, a good place to start is with Accelerating Climate Ambition and Impact: Toolkit for Mainstreaming Nature-Based Solutions into Nationally Determined Contributions[19] published by the United Nations Development Programme. *Also see Appendix: Additional Resources.*

Whether you are using global, national, or local data, the topics below will have to be addressed in any NCS analysis. This phase is likely to take the longest, and tends to be rather iterative as the scope of the analysis may need to be adjusted as new information is integrated.

Previous page: Yakima Valley agriculture detail in south central Washington, U.S. © Benjamin Drummond/TNC

Establishing the Baseline

For NCS to count as climate change mitigation, the actions must capture more carbon, or reduce more GHG emissions, compared to a baseline scenario. This baseline quantifies what emissions and/or sequestration would look like if no *additional* mitigation actions are taken. In some cases, complexity or data paucity will complicate attempts to estimate the baseline accurately, but nevertheless this is an important step that should be carefully considered. When establishing a baseline for your country or area, keep the following in mind:

Data should be recent. Establishing an accurate baseline requires relatively recent data (from the last decade or so) since older data may no longer reflect current conditions. If you lack recent national data, you may consider using global data as an alternative.

Data should include multiple years. It's important to look at emissions across multiple recent years to account for year-to-year variation. For instance, the most recent available data may be from a year that experienced unusually high or low emissions compared to average (e.g., due to a tropical storm, development boom, global pandemic, etc.). Using data from multiple years will allow you calculate a yearly average that will smooth out outliers. If there is a significant upward or downward trend in recent years, you will also want a baseline that reflects that trend. In many cases, it is appropriate to use around 10 years of data.

Keep it simple. Sometimes people use sophisticated models to try to predict a baseline for the future, but studies have shown that sophisticated prediction models can miss the mark[20]. In general, we have found that historical data best predict future trends and are simpler to understand. That said, it is possible to improve your predicted future baseline with additional insights about your country's future plans. For example, you might account for large infrastructure projects that are already planned (e.g., new oil extraction facilities that will result in forest or peatland loss).

Focus on human actions only. GHG fluxes that are outside of human control should not be used as a reference in an NCS analysis. For example, in Canada, most forest cover loss occurs in remote locations due to wildfire and insect disturbance. Unless humans can do something to reduce those natural disturbances, you would not need to include them in the baseline. Instead, the focus should be on the forest areas converted to other land uses or otherwise affected by human interventions.

Existing, ongoing activities count as part of the baseline. It's important to recognize that existing governance conditions and efforts to protect, manage, or restore natural lands should be included in the baseline. For example, if tree planting after a clear-cut is already required by law and that law is generally enforced, this action would not be considered *additional* mitigation under the NCS framework. Conversely, there may be situations where historical efforts should not be included in your baseline if there is no guarantee that those efforts will continue (for example, international development projects, investments from philanthropists, or government programs under a particular political regime). This can be seen in how investments have fluctuated over time in the U.S. with the Department of Agriculture's Conservation Reserve Program and in Canada with windbreak establishment programs.

Determining Extent of NCS Pathways

Once the baseline is established, you can begin to quantify NCS mitigation actions. The first step in doing so is to identify the **extent of opportunity**. For many pathways, the extent is the land area where implementation can occur, usually measured in hectares (ha). For others, the extent may be based on non-area metrics (e.g., the *manure management* pathway is measured in head of cattle).

When identifying the relevant land area, it may be **useful to develop maps** in order to steer implementation towards appropriate locations and to engage with policy-makers and local stakeholders (everyone loves a map!). However, detailed maps require time, resources, and data to create. Similarly, you may not know the potential extent of a given ecosystem, such as when peatlands were drained hundreds of years ago. If you are unable to develop maps, you can use non-spatial information to identify and quantify areas of opportunity, such as **data in table format** on how forest cover has changed through time.

Whether creating maps or not, **be sure not to double-count fluxes for multiple pathways in the same area.** For example, an opportunity to avoid conversion of a forested peatland to drained cropland could fall in either the *avoided freshwater wetland impacts* pathway or the *avoided forest conversion* pathway, not both. The estimate of mitigation, which would consider biomass carbon and various GHG fluxes, remains the same — it is simply a matter of where it is counted. Note that some pathways can overlap spatially without double counting. For example, *grazing optimization* practices and planting *legumes in pastures* and can both be implemented in the same land area. Typically, **if a wetland pathway is an option for a specific area, we recommend counting it as such** because wetlands can have additional GHG fluxes (e.g., methane) and distinct soil conditions compared to other systems. You might also make decisions based on cost. For example, for an area of low-productivity pasture, NCS options may include *reforestation* or *grazing optimization*. As *reforestation* might be more expensive to implement, you might choose to allocate the area to *grazing optimization*.

In general, the goal at this step is to identify the biophysical maximum opportunity — the greatest area or extent that is available for NCS intervention. To increase policy relevance, you may choose to further **winnow the biophysical maximum based on additional criteria** such as costs or feasibility. For example, in the NCS Canada analysis, we limited our tree planting area to locations within 1 km from a road, assuming that it would be too labor- and cost-intensive to plant any further away from the road[15]. Depending on whether the NCS pathway under consideration relates to protection, improved management, or restoration, you will use different methods for identifying the extent of opportunity.

PROTECT PATHWAYS

Protect pathways prevent the loss or degradation of ecosystems. To appropriately quantify their extent, two key sources of information are required: **1) Where are ecosystems located? 2) What portion of those ecosystems are threatened with disturbance or conversion to other land uses?** This second question is critical; a common mistake in mitigation planning is to prioritize areas that store large amounts of carbon without also asking whether those areas are at risk due to human activity. While those areas may be important to protect for biodiversity or other reasons, without appropriately accounting for *additionality* in this manner, climate change mitigation cannot be legitimately claimed.

Aerial view of Parque Nacional Natural Sierra de Chiribiquete in Colombia. © Erika Nortemann/TNC

It can be a challenge to identify locations that are likely to be threatened. If it's not clear where protection is needed, we recommend looking at historical trends. In some cases, **spatial data** is available through national-level surveillance mechanisms or global-scale tools such as Global Forest Watch. In other cases you may have to rely on aspatial data. For example, if you know the average area of peatland disturbance across the last ten years, you could use that average to predict the potential area of avoided disturbance going forward. This type of calculation can make it hard to map protection pathways spatially, but you might be able to identify sub-national locations (e.g., states, provinces, or counties) with higher historical rates of disturbance and thus higher rates of potential mitigation.

As protect pathways incorporate threat, their extent is generally expressed in terms of the predicted *rate* of loss, usually in hectares lost per year. This contrasts with restore pathways, which generally express extent in terms of the *total* potential restored area (ha).

When is a forest a forest?

Be sure to clearly define how you're categorizing types of land cover. Countries differ in what they consider a "forest." Some countries consider forests to be any location greater than a particular size (e.g., 0.5 ha) that has at least a certain proportion of tree cover (e.g., 10% or 25%)[21]. Global-scale datasets often use a 25-30% tree cover threshold. Be sure to use a threshold that is relevant to your purpose, audience, and the data being used. **Whatever threshold you choose, use the same threshold throughout your analysis.**

When is a wetland a wetland?

Be sure to clearly define your wetlands; many people use soil type (e.g., histosols) to delineate wetlands.

MANAGE PATHWAYS

Manage pathways improve management of working lands in ways that offer climate change mitigation while maintaining commodity production[22,23]. As with protect and restore pathways, the extent for many manage pathways is expressed in terms of the land area where practices could be implemented — but other metrics may be used. For example, the *nutrient management* pathway is based on quantities of fertilizer applied to fields. While it may not be possible to develop detailed spatial maps of these opportunities, you should be able to estimate extent with a metric relevant to the pathway.

Pastures are Political

Several manage pathways include strategies related to livestock grazing. However, the IPCC and others highlight the immense climate change mitigation potential of society shifting towards a plant-based diet, which would free up pasture lands for restoration and reduce direct emissions from livestock as well as indirect emissions from widescale deforestation associated with conversion of forests to pasture lands[24,25,26]. For this reason, we count some pasture lands as eligible for restoration. However, this may not be politically or socially feasible in your location, so use your best judgement on how to treat pasture lands for analysis.

RESTORE PATHWAYS

Restore pathways increase the land area or functionality of ecosystems that have been degraded or converted from their historical state[2]. NCS only include activities that restore historical land cover. For example, we would not include tree planting in native grasslands. Tree plantings in grassland systems are often not successful, can reduce biodiversity, and can adversely affect soil carbon.

To quantify the extent of opportunity for these pathways, you will need to know **where each land cover would naturally occur in the absence of human disturbance**. If you don't know the natural extent of a given ecosystem, for instance if seagrass was lost long before mapping occurred, you may consider using ecosystem maps to develop a proxy.

Next, you will need to know the **current extent of the relevant ecosystem**. Subtracting the current extent from the historical extent of natural areas will leave you with an estimate of how much has been converted for human use. You may be able to map these locations or you may simply have aspatial estimates. Next, you will want to remove locations that are unlikely to be restored, like urban areas (unless you're considering *urban canopy cover*), productive croplands, open water or ice, mountain tops, etc. The remaining extent represents the maximum area that can be considered for restoration. As mentioned above, you may want to further filter this area to find locations that are more feasible, such as those that are lower cost, easier to access, or offer more co-benefits.

As restore pathways apply to future scenarios of restorable land, their extent is generally expressed in terms of the *total* potential restored area, usually in hectares. This contrasts with protect pathways, which generally express extent in terms of predicted *rate* of loss (hectares lost per year).

Reforestation Tips

- Pick a tree cover threshold that will mark the transition to forest (*see "When is a forest a forest?", page 33*).
- Double check that the land was historically forested and not another ecosystem (e.g., grassland). Determining what is considered "historically forested" is not always straightforward. It depends on the timeframe selected, and in some cases whether the areas in question were subject to use of fire and other management practices by local Indigenous Peoples over long time periods. We recommend basing your decision on available data for a relevant time period and stakeholder conversations. Apply this consistently throughout your NCS analysis.
- Avoid areas that are infeasible or undesirable for new forests (e.g., productive agricultural lands).
- Prioritize a diverse range of native species over non-native species or monocultures.
- Keep in mind that forests grow slowly and that areas appropriate for forests are shifting under a warming climate. Prioritize areas that are likely to be stable for forests over the long term.

A woman holds a young tree to be planted in East Kalimantan, Indonesia. © Nick Hall/TNC

Calculating Flux of Greenhouse Gases

In addition to extent, it is also important to estimate how NCS changes the transfer, or "flux," of GHGs between the land and the atmosphere. GHGs relevant to NCS include carbon dioxide (CO_2), nitrogen gases (primarily N_2O), and methane (CH_4). Depending on the pathway, one or all of these gases may be relevant. Typically, flux is estimated by compiling the best-available estimates from the literature.

To enable comparisons across pathways, we recommend converting all GHGs into **carbon dioxide equivalents (CO_2e)**. Conversion requires multiplying a GHG by a conversion factor agreed upon and standardized by the scientific community. NCS analyses generally use the following conversion factors, based on a 100-year time horizon, from Neubauer & Megonigal (2015)[27]:

Converting GHG to CO_2e

Gas	Time frame (years)	Sustained-Flux Global Warming Potentials (SGWP)
CO_2	Any	1
CH_4	100	45
N_2O	100	270

For instance, to convert 10 tons CH_4 to CO_2e, multiply by 45 to get 450 tons CO_2e. In some cases, especially for agricultural pathways, it may be appropriate to consider using GWP[28,29], which accounts for short-lived climate pollutants as a pulse. Whatever conversion factors you use, make sure to cite them in all NCS analysis reports, and track your units carefully. It can be helpful to also give estimates in their original units so that it is easy to convert back and forth between CO_2e and specific GHGs as needed.

3.

+1 for the Planet

To track which direction fluxes are being transferred in your analytical equations, we use positive (+) notation to denote increased sequestration or reduced emissions (i.e., to indicate additional storage in the land sector). However, you might encounter other researchers showing flux values from the perspective of the atmosphere, using negative (-) values to denote increased sequestration or reduced emissions. Either is fine, as long as you are consistent throughout the analysis. Make sure everyone on your team is using the same sign convention!

Not Just Carbon

We recommend not using "carbon" as shorthand for CO_2 or CO_2e, since some analyses might use carbon (C) as the actual unit of measure, especially for ecosystem stocks. Mistakes are common, and impactful, since one metric ton of carbon equals ~3.67 tons of carbon dioxide. **Use the formula $CO_2e = C*(44/12)$ when converting units between C and CO_2e** to reflect the difference between the atomic weight of CO_2 (44 atomic mass units) and C (12 atomic mass units). Whatever notations you use, always be clear about what units you're using.

Evening view of the forest of East Kalimantan, Indonesia, Borneo near the Lesan River Orangutan Survey Site. © Mark Godfrey/TNC

For **protect pathways**, the main fluxes are emissions avoided by preventing conversion or continued degradation. For example, the flux associated with *avoided forest conversion* includes the carbon stocks that are lost due to vegetation and soil disturbances (usually expressed in units of metric tons of carbon per hectare, represented as t C/ha or Mg C ha^{-1}). Theoretically you could also account for the lost ability of the system to sequester more carbon in the future, but it is more conservative (and simpler) to exclude given uncertainty around future climate impacts on ecosystems (*see "Considering Climate Feedbacks" on page 39*). For **manage pathways**, flux is the increased sequestration or reduced emissions due to improved management practices compared to the baseline scenario. For **restore pathways**, the largest flux values are often due to additional sequestration of GHGs in vegetation and soil (usually expressed in units of metric tons of carbon sequestered per hectare per year, represented as t C/ha/yr or Mg C ha-1 yr^{-1}), but restoration may also help to avoid emissions that come from degraded ecosystems. For instance, when peatlands are drained it may take years for them to become fully degraded (or converted) and they will emit GHGs during this entire time period. Therefore, restoring peatland hydrology both improves sequestration while simultaneously preventing emissions.

Figuring Out Forest Fluxes

One way to calculate flux is to use a **committed emissions** approach, where you assume, for ease of accounting, that all the carbon from harvested or disturbed vegetation is "committed" to the atmosphere immediately after disturbance. However, this is often an overgeneralization. Leftover woody debris may decay for many years post-deforestation before it stops emitting GHGs. On the other hand, harvested wood may provide building materials than are more sustainable than concrete or steel, or energy sources that substitute for more carbon-intensive fossil fuels. Questions about wood product storage and substitution are complex and require data from life cycle assessments[30] to figure out the net impact across the relevant system.

As you calculate flux for each of your NCS pathways, here are some additional factors to keep in mind:

Baseline: While baselines are often incorporated into extent estimates, sometimes NCS flux estimates must also be expressed relative to a baseline. For example, restored wetlands will emit methane, but eventually they will emit less methane than unrestored wetlands. The NCS flux will thus represent the improvement in methane emissions due to NCS implementation.

Location: Fluxes vary across space. We find, for example, that carbon sequestration from letting forests regrow across the U.S. varies over 25-fold depending on the location[31]. While there are advantages to using spatially precise estimates wherever possible, sometimes the best available information will be from estimates that apply over large areas. Use caution when downscaling measures of flux from a large area like a country to smaller regions like a state, province, or municipality as average values from a large area may not provide an accurate value for your location.

Non-GHG factors: Other non-GHG factors can influence mitigation potential, such as albedo. **Albedo** refers to how different land covers reflect or absorb heat from the sun. Increasing dark tree cover, particularly in places with substantial snow cover, can cause warming that undermines the mitigation benefit of carbon sequestration in trees. For example, for the Canada analysis, albedo and carbon sequestration estimates were combined to identify locations where restoration of forest cover is likely to have positive climate outcomes. In addition, the warming effect (known as radiative forcing) of albedo was converted into CO_2e to facilitate comparisons across pathways (*see the Materials and Methods of "Natural Climate Solutions for Canada" by Drever et al. for detailed conversion methods*). Other factors, such as **evapotranspiration** and **volatile organic compounds**, can also affect estimates of NCS mitigation, but most assessments do not account for these factors due to their likely small effects and lack of available data.

Choosing a Time Horizon

Natural systems are dynamic, and so are NCS. **Fluxes of GHGs will change through time, as will the extent of opportunity.** To ensure NCS estimates are well-crafted and policy relevant, you will need to specify the time frame of your analysis. To do so, **think about time horizons that are relevant to your target audience** or other stakeholders. Are there dates associated with your country's NDC? To enable comparisons, you will need to **use the same time frame across all pathways.**

The time horizon will determine how you report the benefits of an NCS pathway. Typically, we report **annual mitigation potential in a specific, policy-relevant year** (e.g., Gt CO_2e/yr in 2030). However, you may also report total mitigation that accumulates over multiple years, for example, Gt CO_2e between 2020 and 2030.

Underlying these estimates are also assumptions about how quickly NCS activities will be implemented. Do you assume that all actions start in the first year? Do you build in time for stakeholder outreach, such as to the farmers who could adopt improved management practices? How long will it take to produce necessary materials, such as the tree saplings needed for reforestation? Choose an adoption scenario that makes sense to your target audience, but keep in mind that the time frame for implementation will influence your final estimates.

As an example, two timeframes were selected for the NCS Canada analysis, 2020–2030 and 2020–2050, to align with Canada's NDC commitments to reduce emissions by 2030 and reach carbon neutrality by 2050. Though analysis was completed in 2020, we assumed that tree planting would not begin until 2022, since time would be needed to develop saplings to plant. As a result of this delayed implementation and the initial slow growth of trees in Canada, the mitigation potential of restoration of forest cover in 2030 was very small. However, even though we modeled no additional planting after 2030, the benefit of restoration of forest cover grew 16 times by 2050.

Considering Climate Feedbacks

Natural systems have the potential to help protect us from climate change, but at the same time, they are also being impacted by climate change. These climate feedbacks may impact future NCS opportunity. In many cases, feedbacks are negative, increasing the likelihood of drought, fire, flood, and other disturbances. But in some cases, feedbacks can be positive, for example, when warmer temperatures lead to longer growing seasons in higher latitudes and when increased CO_2 boosts plant growth. It is extremely challenging to project what is going to happen to the NCS opportunity in any specific location and modeling climate feedbacks is an active area of research.

In prior NCS analyses, we did not account for climate feedbacks because we assumed impacts would be small in our analysis time frame (in many cases, present day to 2030). But as global warming progresses and/or analysis time horizons lengthen, it will be increasingly important to include climate feedbacks in models. For instance, think about whether changes in climate will impact the feasibility or the mitigation benefits of your NCS pathways within your time horizon. If yes, consider whether you have enough information to incorporate climate feedbacks into your analysis. You might decide, for example, to exclude locations with high fire frequency from your reforestation extent of opportunity, even if those places historically supported forests, under the assumption that they will experience even more frequent fires in the future. Even if you do not have enough information to quantify these considerations in your analysis, they are still useful to examine and include as discussions in your NCS report.

Future research will continue to refine our understanding of the role of climate feedbacks on future NCS opportunities, but this research should not delay the urgent need to activate NCS as soon as possible. The most efficient way to avoid climate feedbacks is to drastically reduce the concentration of GHGs in the atmosphere via broad, rapid deployment of *all* climate solutions.

Marathon Grasslands Preserve in west Texas, U.S. This diverse Chihuahuan Desert grassland habitat supports an array of wildlife, including the federally endangered northern aplomado falcon. © Jerod Foster/TNC

Characterizing Costs

Costs, or cost reductions, are a major driver of NCS implementation. Generally, NCS implementation requires up-front investments (e.g., the purchase of new equipment needed for precision fertilizer application, tree planting stock, etc.). But in some cases, NCS can reduce costs, such as the more efficient use of nitrogen fertilizers reducing fertilizer costs for farmers. NCS assessments to date have generally reported **net costs**, that is, the combined total of cost increases and cost reductions, resulting from NCS over a given time scale.

A range of data sources will likely be required to approximate all relevant costs. **Costs can be placed into three broad categories:**

- **Implementation costs** include costs associated with program design, planning, training, technical assistance, site preparation, deployment management actions, maintenance, and replacement.
- **Opportunity costs** are the change in profits associated with changing from the baseline activity to an NCS implementation activity. For example, establishing riparian buffers in agricultural lands may reduce the amount of land in production in any given year and hence change total crop yield and associated profits.
- **Transaction costs** associated with NCS are often overlooked, and are more difficult to quantify[32,33,34]. They include overhead costs, such as the time landowners spend learning about and familiarizing themselves with an NCS program or practice; the resources a program needs in order to identify, reach out to, and engage policy makers, prospective participating landowners, or other key stakeholders; or the time landowners and NCS program staff spend drawing up contracts and monitoring NCS implementation. If an NCS project is being used to generate carbon credits, then transaction costs also include the cost of project registration, monitoring, verification, issuance, and retirement of credits.

Net costs for implementing NCS also depend on the price point of carbon.

In our NCS assessments, we typically consider mitigation potential at a price point of 100 USD per metric ton of CO_2e because recent studies suggest that this is what it will cost to achieve the Paris Agreement goals[35,36]. In addition, future climate change above 2°C is likely to cause greater damage to humanity than the costs of limiting climate change to 2°C[37,38]. Thus, we consider mitigation strategies that cost 100 USD/tCO_2e to be cost-effective. That said, you should pick a price point that's right for your analysis. For example, 10 USD/tCO_2e might better reflect the current carbon price in relevant voluntary or regulatory markets, or 50 USD/tCO_2e might align with specific policy ambitions in your country (*see Appendix: Cost Estimates*).

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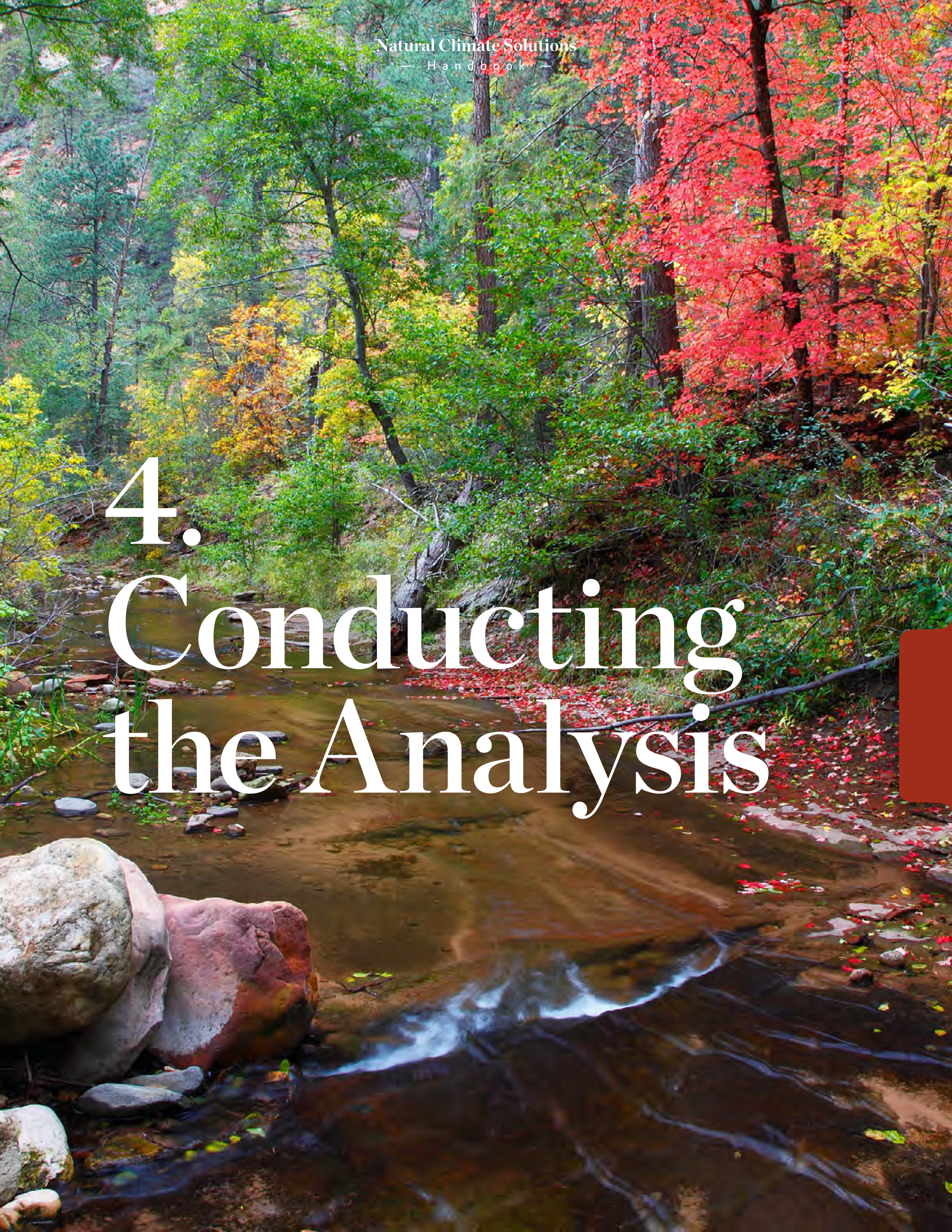

4. Conducting the Analysis

Estimating Mitigation

Now that you have set the parameters for your analysis and compiled information on baselines, extent, flux, and costs, it is time to quantify the mitigation potential for each NCS pathway. It may be helpful to reference prior NCS analyses[2,15,39] and emulate the methods with your specific datasets.

The equation for each pathway is simple:

$$\text{Extent} \times \text{Flux} = \text{Maximum Mitigation Potential}$$

If you have converted all flux GHG units to CO_2e, multiplying annual flux and extent values together gives you an estimate of maximum biophysical mitigation potential in CO_2e/year for that pathway.

You may also consider differences in mitigation potential for multiple activities within a single pathway. For example, multiple *reforestation* activities might be relevant to your locality, such as natural regrowth, assisted regeneration, and/or active tree planting. In this case, it might be useful to disaggregate *reforestation* into separate activities to help decision-makers understand the merits of investing in one or more of these options.

Quantifying Uncertainty

It's good practice to quantify uncertainty around all NCS estimates as the range of extent and flux (and thus mitigation) can vary widely. **Reporting only mean or median numbers for estimates with large uncertainty ranges can inadvertently mislead decision-makers.** Typically, quantifying uncertainty involves determining an expected range (e.g., a 95% confidence interval) around each estimated parameter to indicate the lowest and highest values that you expect to occur. The best way to calculate this range for each variable is to find multiple independent estimates in the literature, and then use the mean and standard deviation around that mean in your analysis. If multiple independent estimates are not available, you might consider using expert judgement to obtain estimates via the Delphi process[40,41,42]. This involves a 3-step process: 1) several experts are asked to submit their best estimates, 2) answers are compiled anonymously and distributed back to the experts, 3) experts are given the opportunity to revise their estimates based on the other responses. The final range of estimates can serve as the uncertainty range for your analysis.

Once you have estimates of uncertainty around all of the variables in your calculations, you will need to combine those to estimate overall uncertainty (also known as error propagation[43]). While the IPCC has developed recommended approaches for estimating uncertainty[44], we have found that these general approaches do not always capture the complexity of our analyses. For example, if there are multiple variables combined in a formula

Previous page: West Fork of Oak Creek Canyon in Coconino National Forest, Arizona, U.S. © Gavin Emmons/TNC

Sunset over rice fields on a farm along the border of the Lore Lindu National Park, home to one of the largest intact forests in the country, situated in central Sulawesi, Indonesia. © Bridget Besaw/TNC

to estimate mitigation or if the uncertainty values do not form a normal distribution, we have opted to use an analytical tool called a Monte Carlo Simulation to propagate uncertainty from multiple sources. With this method, which can be run in many statistical programs, you would randomly draw an estimate from the uncertainty envelope around each variable and then use that number to estimate overall mitigation for the pathway. By repeating this process many (for example, 10,000-100,000) times you can estimate overall uncertainty for a pathway (or for all pathways combined). *See* this guidance document *for more information about Monte Carlo Simulations*[45].

There will be other sources of uncertainty that will be hard to quantify, such as how climate feedbacks will impact your mitigation estimates. When communicating the results of your NCS assessment, it is important to 1) note that the range of possible outcomes could be larger than what you've estimated given these unknowns, and 2) document how your assumptions, different potential future scenarios, and variability in underlying data contribute to the ranges reported.

Incorporating Costs: Marginal Abatement Cost Curves

Once the mitigation assessment is complete, integrating cost assessments into your NCS analysis can better inform decision-making. One way to do this is to create marginal abatement cost (MAC) curves for each pathway, which graph the cost of achieving each additional metric ton of CO_2e sequestration or avoided emissions.

The MAC of a project exclusively focused on mitigation is calculated by dividing the total costs of the project by the total mitigation the project achieves. For multi-objective projects, if the mitigation costs can be separated from the total costs, the MAC is calculated by dividing the mitigation component costs by the total mitigation the project achieves. If not, then estimating the MAC requires careful analysis to identify the additional costs incurred for the mitigation activities. Costs and mitigation must be counted over the same time horizon (e.g., 30 years). To build a MAC curve, arrange all projects (also known as "mitigation increments"), represented by a point or a bar, on a graph from lowest to highest MAC. The resulting curve identifies the total mitigation. **A well-constructed MAC curve identifies the total mitigation that can be achieved at a given cost per ton CO_2e. This helps identify key price points for activating NCS implementation**.

Bison grazing at Broken Kettle Grassland Preserve in the Loess Hills of Iowa, U.S. The Loess Hills is Iowa's largest contiguous native prairie and bison will help return the area to a more natural condition. © Chris Helzer/TNC

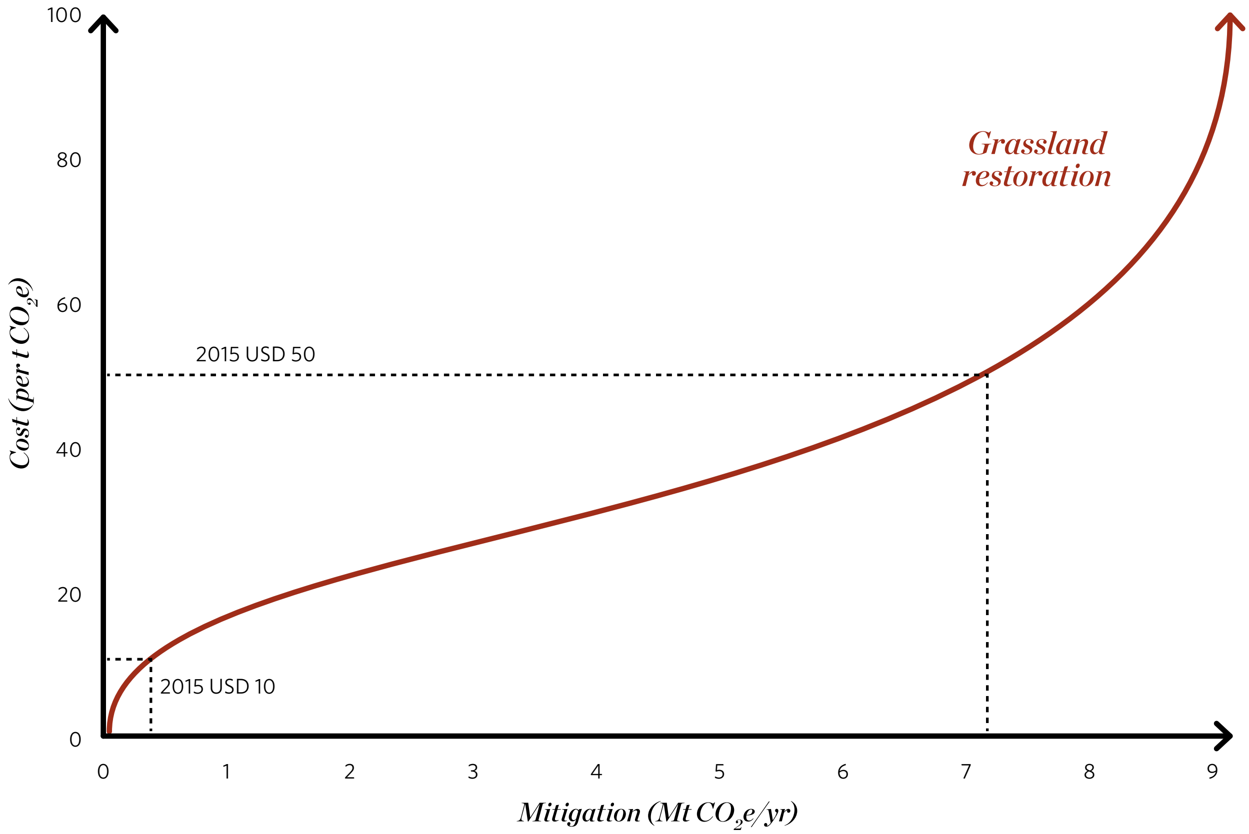

Figure 8: Marginal Abatement Cost Curve for U.S. Grassland Restoration[39]

Here's an example of a MAC curve for *grassland restoration* in the U.S. It shows that approximately 9 Mt of CO_2e per year could be removed from the atmosphere assuming a carbon market price of 100 USD per ton of CO_2e, if all potentially available grasslands in the U.S. were restored.

The y-axis shows the cost of each additional ton of CO_2e removed and the x-axis shows mitigation. The curve slopes upward for each successive additional ton of CO_2e removed because lands vary in their cost per hectare and in their mitigation potential per hectare per year. As mitigation in the figure is arranged from lowest cost on the left to highest cost on the right, the MAC curve thus assumes that grassland restoration is implemented first on lands that achieve mitigation at the lowest cost per unit. The figure shows that at a cost of 10 USD/tCO_2e, almost no grassland restoration is possible and thus very little mitigation can be achieved. However, if landowners or managers are paid up to 50 USD/tCO_2e, over 7 Mt of CO_2e could be sequestered each year.

MAC curves allow estimation of the total budget needed to achieve a given amount of mitigation. The example above shows annual mitigation in 2025, but it could be converted to a MAC curve that shows total cumulative mitigation during the analysis time period of 2019-2025. Using that cumulative MAC curve, the total budget needed for any given abatement quantity can then be estimated by multiplying each ton of CO_2e mitigated during the analysis time horizon by its respective marginal abatement cost, and then summing all these values (that is, analytically, the total cost is given by the area below the MAC curve, up to the chosen total abatement quantity).

Finally, **MAC curves can help decide what NCS are currently economically feasible**. It is important to remember that most NCS pathways have non-carbon co-benefits that enhance people's wellbeing and advance SDGs[46,47]. These benefits can be more difficult to value in monetary terms and generally are not included in MAC estimates, unless they accrue to the landowners who implement the mitigation action, which would reduce the landowners' opportunity costs of mitigation. In some cases, those **co-benefits can have a higher economic value than the mitigation itself**. In all cases, they have **real economic value for people that reduces the cost of NCS for society as a whole compared to the costs indicated by MAC curves.**

For example, expanding *urban canopy cover* might have a very high cost per tCO_2e sequestered and so might not seem to be competitive with mitigation approaches. However, urban trees also provide stormwater management, improve people's respiratory health and reduce their heat exposure, provide mental health benefits, and reduce peak electricity demand in areas where air conditioners are used[48]. The combined value of this suite of benefits often exceeds the costs of tree planting and management[49]. Thus, while urban tree planting may not be a cost-effective climate change mitigation strategy, in many places it is a strategy that produces net economic and human benefits, with mitigation as a co-benefit. *Also see Appendix: Cost Estimates*.

MAC curves can be constructed using two basic approaches. The first, "**bottom-up**" approach, uses site-specific information on costs and mitigation from actual projects[15,39]. This approach can reveal context-specific transaction costs (expenses incurred for activities that enable implementation of the mitigation project, such as landowner engagement and contract development), which are often large. However, it has several limitations. First, it usually requires extrapolating data from a limited set of projects to the remaining area identified as potentially suitable for implementation of that pathway. Second, existing NCS projects may not be representative of other areas. For example, existing projects may be demonstration projects and may involve scientific studies, which would tend to increase costs compared to projects that do not have a scientific purpose. Similarly, future projects may have lower costs than existing ones because they can draw on insights gained or because they can realize economies of scale. Or, conversely, current projects might have been implemented in the most conducive locations (low cost, high mitigation) resulting in future projects being less cost-effective.

The second, "**top-down**," approach employs modeling and empirically observable data, analyzing land cover or management data as a function of independent variables (e.g., agricultural prices, soil characteristics, slope, proximity to roads and urban areas). The models used can vary widely, from relatively simple spatial-econometric models[50] to complex multi-sectoral optimization models[51]. This modeling-based approach is well suited to large land areas, and allows the systematic exploration of how land use or management would respond to specific interventions such as varying carbon prices. The limitation of this approach is the need for spatially complete and sufficiently high-resolution information about key model variables, such as land values or land use. In addition, unlike bottom-up approaches, top-down approaches cannot estimate transaction costs directly; they can only add them on in an ad-hoc manner.

Accounting for Future Cost Changes: Discounting

An NCS project incurs costs and produces mitigation over multiple years. Moreover, costs usually occur early on while mitigation benefits will occur over decades or centuries. Empirical evidence shows that individuals and societies value costs and benefits incurred today higher than costs and benefits incurred at some future point in time[52,53]. **To appropriately compare present and future costs and benefits, we use a process called discounting, which expresses the monetary values of future costs or benefits in their present-value equivalents.**

A discount rate is used to quantify future values in present-day equivalents. The choice of discount rate has a large impact on the economics of climate change mitigation projects, so great care should be taken to identify the correct discount rate used for a given project. Mitigation projects seeking **private investment** generally should use the investor's opportunity cost of capital as the discount rate, which can be approximated using borrowing interest rates or pre-tax rates of return. Conversely, analyses of **publicly funded** mitigation projects that deliver benefits to the population at large should use social discount rates that reflect how people in a country trade off present for future consumption.

Furthermore, there is widespread agreement among professional economists that analyses of publicly funded projects should use declining social discount rates[54]. This is especially true for cost-benefit analyses of mitigation projects, due to the long time horizon over which benefits occur. While the estimation of social discount rates is a complex undertaking, many countries have adopted specific social discount rates to be used by domestic agencies in public policy analyses, and estimates of social discount rates are available for nearly every country[55,56].

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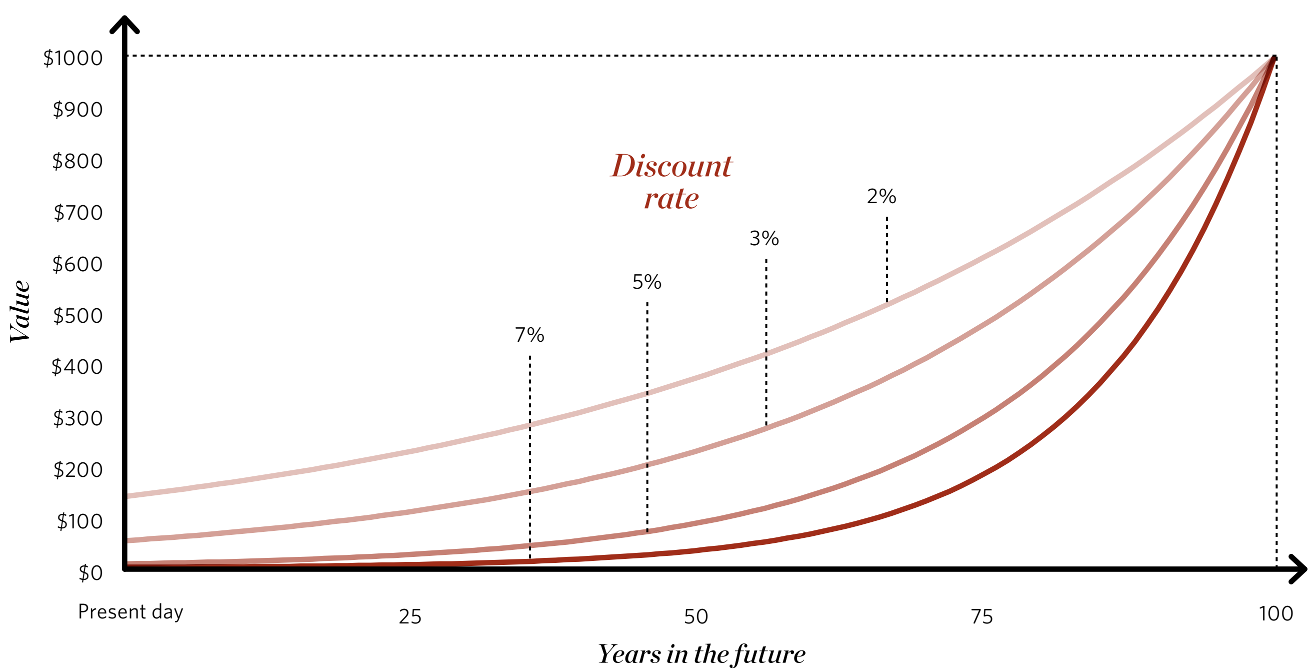

Figure 9: Example of impact of different discount rates on the present value of $1000 received 100 years in the future

Next Steps

To date, NCS analyses have largely emphasized understanding how much mitigation is available, and how that varies by cost considerations and location. While it is critical to answer these questions, there are likely additional steps needed to make the information the most useful for decision-making and action on the ground. **Assessing NCS opportunity must be followed by concrete action to activate it.**

DON'T FORGET OUTREACH!

Beyond your primary target audience, there are likely other relevant decision-makers, policy and science experts, partner organizations, impacted communities, and more who will be interested in and able to use the results of your analyses. We recommend publishing NCS analyses in peer-reviewed, open-access journals whenever possible. This ensures that your methods and results are credible, transparent, and available to a wider audience than you could reach through direct engagement. However, we have also found that targeted and direct engagement with key user groups, such as government agencies, helps people to better understand and buy into the findings.

In addition, it can be helpful to generate companion pieces, such as a policy brief or a web page. Nature4Climate is one example of how multiple organizations have used a website and associated communication tools to share analytical results and other information. Your story may be widely circulated through social media, news articles, or blogs. Photos, infographics, and compelling case studies can increase the impact of these methods of communication, especially as you expand to a broader audience.

MOVING FROM "HOW MUCH?" TO "HOW?"

Depending on your goals, you may need to take your initial analyses further. For example, you might conduct more detailed cost-effectiveness studies to determine return on investment or investigate additional incentives to action (*see Appendix: Cost Estimates for further examination of cost considerations*).

Similarly, while mitigation is important, other benefits of NCS implementation may often drive action, such as biodiversity and ecosystem services (*see Appendix: Co-Benefits*). You may want to directly measure and map relevant co-benefits to share with your target audience and other stakeholders.

Determining how to fund NCS projects is another key consideration for implementation. When used appropriately, carbon offsets and other pay-for-performance mechanisms may be options, as well as a source of revenue for landowners (*see Appendix: Carbon Offsets for an introduction to offsets and their use*).

HUMAN IMPACTS

In this guide, we have barely begun to scratch the surface of understanding possible social and human well-being impacts, and much more research is needed in this space. NCS interventions can contribute to advancing SDGs and improving people's quality of life, for example through building food security, governance, and sustainable economic opportunities. At the same time, it is crucial to recognize and improve inequities related to climate, both with regard to historical injustices and future compounded impacts on marginalized communities. While implementation of NCS projects can promote climate justice, human rights, and gender equality, this is not inherently guaranteed.

The work of understanding impacts of NCS on various communities must be done for its own sake, but engaging stakeholders and addressing injustices will also make NCS implementation more viable and sustainable (*see Appendix: Climate Justice for further discussion of climate justice*).

HARNESSING TECHNOLOGY

New data and technology are introduced every day, constantly changing best practices for analysis and implementation. The field of remote sensing is blossoming, filling data gaps and generating finer-scale maps of different pathway opportunities in different locations. These advances can reduce uncertainty, improve spatial precision, and help decision-makers more clearly visualize opportunities for implementation. Remote sensing also shows promise for monitoring NCS pathways and understanding whether modeled carbon benefits are, in fact, being realized on the ground.

LEARN FROM THOSE WHO CAME BEFORE, TEACH THOSE WHO COME AFTER

To develop this guide, we drew on lessons learned in five different countries where the NCS framework has been adopted and adapted (*see Country Case Studies for more on the lessons learned from these assessments*). Our hope is that representatives of many other countries will use the recommendations detailed in this guide to conduct their own mitigation potential assessments, and will share their experiences in the future so that we may learn from each other and speed up NCS implementation across the globe.

While each country is different, two key lessons emerged from experiences in Canada, China, Colombia, Indonesia, and the United States:

Building trust and following through are key.

Scientific journals are full of excellent analysis and research that has had little impact on policy and action. Success requires consulting with stakeholders early and often — and following up with the right technical assistance and tools to allow them to use the results of your NCS analysis.

We need to conduct and communicate NCS assessments in a way that allows for understanding of synergies and trade-offs.

Further feasibility research and tools to help explore different implementation scenarios would revolutionize NCS policy-making.

CATALYZING NCS ACTION

Significant resources are needed to unlock NCS potential[57]. Fortunately, funding for NCS has been on the rise, and we sincerely hope the pace and scale of NCS investment — and resulting implementation — will rapidly increase to provide measurable, equitable climate benefits for a livable future.

This guide summarizes what we have learned so far. We look forward to updating it as new studies, methods, and stakeholder engagements improve on current methods. Our hope is that this guide helps others to more quickly complete credible and impactful analyses of NCS potential which will enable NCS implementation on the ground at the scale and pace that the climate crisis requires.

5. Country Case Studies

Eastern Hemisphere

We also share in this guide brief case studies from Canada, China, Colombia, Indonesia, and the United States...

Western Hemisphere

...that demonstrate how teams have adapted the global NCS framework to their needs, including the lessons learned in the process.

Previous page: Misty mountain peaks of Laohegou Nature Reserve, Sichuan Province, China. © Nick Hall/TNC

Canada

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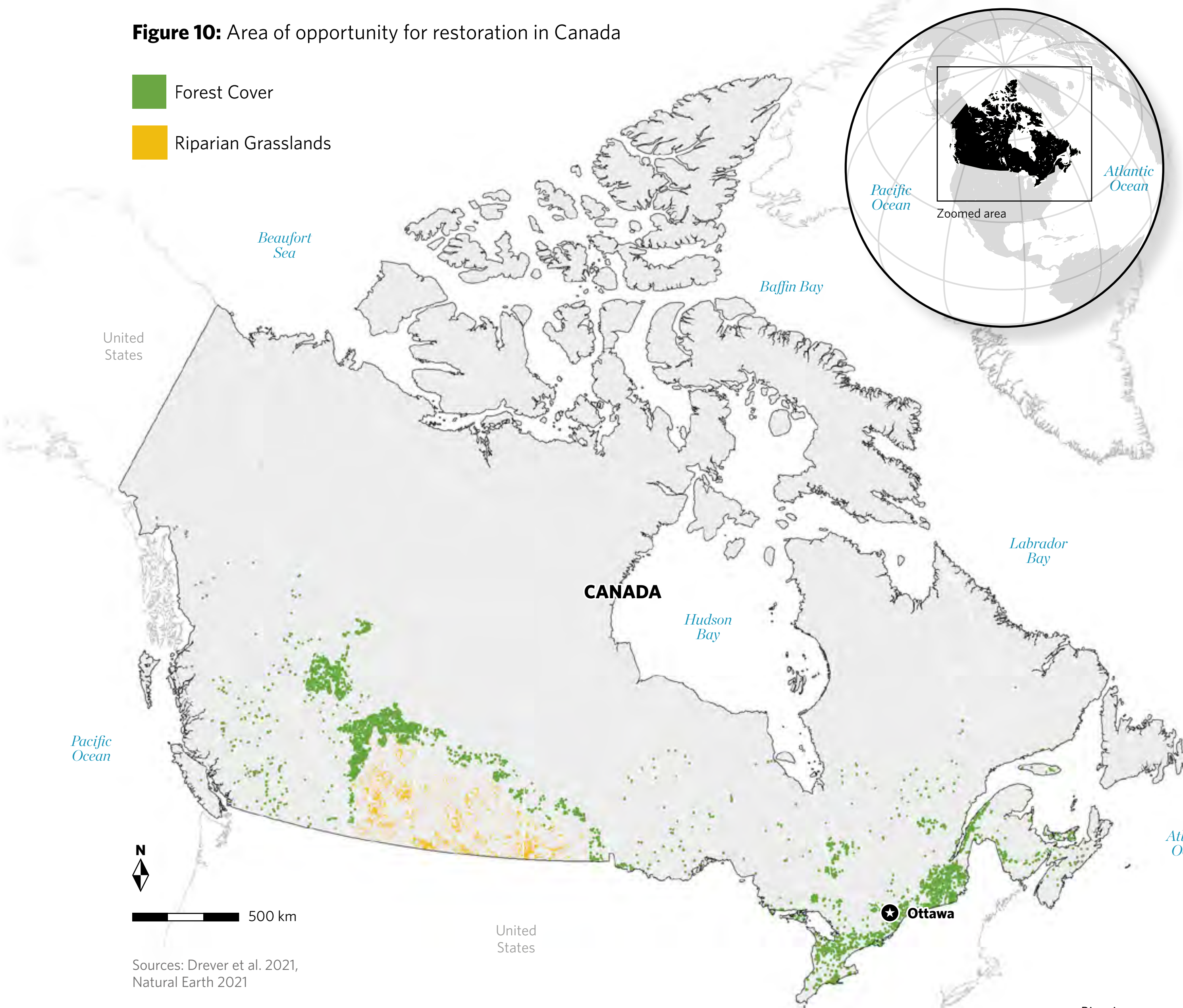
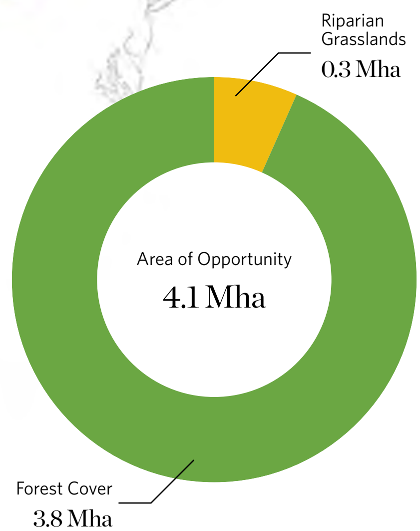
Figure 10: Area of opportunity for restoration in Canada



Sources: Drever et al. 2021, Natural Earth 2021



Under the Paris Agreement, Canada aims to reduce its annual emissions to 511 Mt CO_2e by 2030. Until recently, emissions from LULUCF were not included in emission reductions targets. However, in 2019, Canada committed to decreasing its annual emissions related to LULUCF. In December 2020, Canada announced a strengthened climate plan and a commitment to annual emissions reductions in 2030 of 17 Mt CO_2e/yr from LULUCF and nature-based solutions and 10 Mt CO_2e/yr from regenerative agriculture.

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While Canada is not a large GHG emitter — its emissions are 1.5% of the global total — the country ranks among the top 10 emitters in the world and has one of the highest per capita emissions (15.1 t CO_2e/person/yr)[58]. For the last 20 years, Canada's annual emissions have fluctuated around 700 Mt CO_2e, with the largest contributors being the oil and gas and transportation sectors[59].

BACKGROUND RESEARCH

In December 2020, Canada committed nearly 4 billion CAD over 10 years to the implementation of NCS, principally towards planting 2 billion trees; conserving and restoring grasslands, wetlands, and peatlands; and creating a new fund for NCS for Agriculture. These climate-related investments aim to support another conservation commitment: protection of 30% of Canada's lands and oceans by 2030 under the Convention on Biological Diversity[60].

In line with these commitments, Nature United (The Nature Conservancy's Canada program) made a strategic decision in 2017 to initiate a climate change mitigation program with a focus on NCS. The focus on NCS better supports Nature United's ethos of Indigenous-led conservation than other types of climate action. At this early stage, Nature United staff recognized a lack of foundational knowledge regarding the mitigation opportunity of Canada's natural systems and initiated a research effort to build the evidence base for conservation action, develop a network of expert contacts and put Nature United "on the map" as a convenor of cutting-edge science. Since the beginning, Nature United aimed to build on the capacity and lessons learned by TNC through NCS assessments for the globe and the U.S.

CANADA'S NCS PATHWAYS

The list of potential pathways for analysis was initially generated from a literature review of Canadian studies. This list was then vetted during an initial workshop of invited experts held in February 2019, which saw the creation of ecosystem-specific working groups. For some pathways, we relied on one or two experts to whom the Nature United/TNC team provided support related to accounting, spatial analyses, or economic costing, e.g., *urban canopy cover*, *manure management*, or *nutrient management*. Some pathways the working group considered, such as the use of forest management practices to mitigate the risk of future wildland fires, were discarded after learning there was insufficient existing evidence to move forward with analysis. That said, the research team took the holistic approach of including all pathways relevant to Canada that were feasible to analyze, rather than narrowing to a few pathways that were known to have high potential. The rationale was that, given the lack of information about NCS in Canada, a comprehensive examination of a wide variety of pathways across all ecosystems would have high policy relevance and set the stage for a national conversation about the role of nature in climate action. In addition, since NCS represented the first climate-related program for Nature United, a research initiative would be an effective way to build both a community of practice across sectors and credibility for Nature United as a science-based organization.

Walking along a fallen log in the Great Bear Rainforest of British Columbia, Canada. © Jason Houston

We introduced several novel technical aspects that tailored the analysis to the Canadian context. For instance, while albedo (*see Glossary*) was recognized as an important influence on land-based mitigation, especially in northern landscapes, previous global and U.S. NCS analyses did not include its effect due to complexity and data gaps. We developed novel analyses based on recent albedo mapping[61] to better understand the albedo implications of pathways that expanded tree cover, and accordingly applied an albedo "discount" to those pathways[15]. In addition, we adapted the analysis to include an evaluation of economic costs of mitigation according to the carbon pricing currently in use in Canada. We also used a feasibility criterion for management and restoration pathways, in which we modeled implementation and associated mitigation over 10% of our area of opportunity per year through a 10-year implementation period (2021–2030).

Using NCS to tackle climate change in ways that count towards NDCs will require an alignment between specific NCS pathways and national GHG inventory and reporting frameworks.


Cloudy skies over a grassland in Canada. © Jean Wallace/TNC

LESSONS LEARNED

Country-scale analyses are critical to ground NCS in national realities for implementation. For instance, a surprising finding of the NCS Canada assessment was the large potential role for agriculture. As a northern country dominated by forests, the expectation was that forests would represent the primary opportunities for land-based climate mitigation. However, given that forests are relatively well-managed and that forest conversion is relatively limited, forest NCS pathways showed the least amount of potential mitigation of the four ecosystem types we examined.

Program-level implementation of NCS needs to recognize and build on existing priorities and approaches. Nature United's work to date has focused on Indigenous-led conservation. While the team recognized the value of moving ahead with a collaborative research effort to fill a recognized gap in information about the potential for NCS to deliver mitigation, we need to leverage this science and NCS initiatives in ways that respect Indigenous rights and knowledge, as well as support Indigenous governance, land-relationship planning, stewardship, and economic development—all in recognition that NCS will occur on the traditional territories of Indigenous Peoples.

Differences exist between what our science assessment revealed about potential for NCS and what Canada includes in its targets and accounting framework to measure progress towards emission reductions goals. For instance, the NCS Canada assessment identified avoided peatland conversion as having good mitigation potential. However, there was a misalignment between the mitigation potential we identified and how Canada counts emissions and removals associated with peatland management and land use. Using NCS to tackle climate change in ways that count towards NDCs will require an alignment between specific NCS pathways and national GHG inventory and reporting frameworks. While we were able to document this alignment retrospectively *(see table on next page)*, early engagement of the scientists working in the government department that undertakes reporting would have been beneficial to build this alignment.

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Previous page: Forested islands of Clayoquot Sound of Canada's British Columbia coast. © John Beatty Photography

	NCS Canada Pathways	How pathway is assessed in Canada's 2020 National Inventory Report (NIR)	UNFCCC Category
Forests	**Avoided Forest Conversion**	Emissions/Removals (E/R) counted in Forest Conversion to Cropland, Wetlands, Settlements and Harvested Wood Products (HWP).	Land Use, Land-Use Change, and Forestry (LULUCF)
Forests	**Improved Forest Management**	E/R counted in Forest Land remaining Forest Land (FLFL) and HWP from FLFL.	LULUCF
Forests	**Urban Canopy Cover**	E/R counted in urban trees category of Settlements remaining Settlements (SLSL).	LULUCF
Forests	**Restoration of Forest Cover**	E/R counted in Land converted to Forest Land (forest establishment where previous land use was not forest). Post-harvest tree planting considered reforestation not afforestation.	LULUCF
Wetlands	**Avoided Seagrass Loss**	Not currently included. No activity data available to assess loss consistently across Canada.	LULUCF
Wetlands	**Avoided Peatland Conversion**	E/R counted as Wetlands remaining Wetlands (WLWL) - Peat Extraction (drained and rewetted sites). NIR does not report on conversion of natural wetlands to other land uses. Wetlands categories only report emissions from hydroreservoirs and horticultural peat extraction.	LULUCF
Wetlands	**Avoided Freshwater Mineral Wetland Conversion**	Not currently included. Conversion estimates for Prairie potholes region and Eastern Canada are under development.	LULUCF
Wetlands	**Salt Marsh Restoration**	Not currently included. No activity data available to model restoration consistently across Canada.	LULUCF
Wetlands	**Seagrass Restoration**	Not currently included. No activity data available to model restoration consistently across Canada.	LULUCF
Wetlands	**Peatland Restoration**	Not currently included. No activity data available to model restoration consistently across Canada. Some estimates included in peat extraction model.	LULUCF
Wetlands	**Freshwater Mineral Wetland Restoration**	Not currently included. Estimates for Prairie potholes region and Eastern Canada are under development.	LULUCF
Grasslands	**Avoided Grassland Conversion**	E/R counted as Grassland to Cropland (GLCL) and Grassland to Settlements (GLSL). Includes only native grasslands in Prairies. Grassland loss rates are tracked currently, but estimates are for unbroken grassland - all other elements are in Cropland.	LULUCF
Grasslands	**Riparian Grassland Restoration**	Not currently included. No activity data available to model restoration consistently across Canada.	LULUCF
Agricultural Lands	**Tree Intercropping**	E/R counted in Cropland remaining Cropland (CLCL) - Woody biomass.	LULUCF
Agricultural Lands	**Avoided Conversion of Shelterbelts**	E/R counted in CLCL - Woody biomass.	LULUCF
Agricultural Lands	**Riparian Tree Planting**	E/R counted in CLCL - Woody biomass.	LULUCF
Agricultural Lands	**Silvopasture**	E/R counted in CLCL - Woody biomass.	LULUCF
Agricultural Lands	**Nutrient Management**	E/R counted in Inorganic Nitrogen Fertilizers and Organic Nitrogen Fertilizers (N_2O). No current activity data on levels of implementation.	Agriculture
Agricultural Lands	**Crop Residue – Biochar**	Not currently included.	Agriculture
Agricultural Lands	**Cover Crops**	E/R counted in CLCL (Change in crop mixture; Change in summerfallow (SF)) as two Land Management Changes: Decrease in SF; Increase in perennial.	LULUCF
Agricultural Lands	**Reduced Tillage**	E/R counted in CLCL as change in tillage (Land Management Changes: Conventional to reduced; Conventional to no-till; Other)	LULUCF
Agricultural Lands	**Increased Legume Crops**	E/R counted as direct N_2O emissions from Agricultural Soils (Managed Soils)	Agriculture
Agricultural Lands	**Legumes in Pasture**	Not currently included. E/R could be counted in Agricultural Soils (Direct N_2O emissions from managed soils).	Agriculture
Agricultural Lands	**Manure Management**	Not currently included. E/R could be counted as CH_4 Emissions from Manure Management (handling and storage of livestock manure).	Agriculture

Figure 11: Alignment of pathways from Canada NCS assessment with NIR and UNFCCC categories. Length of colored bar indicates full, partial, or no alignment between NCS pathway and NIR

China

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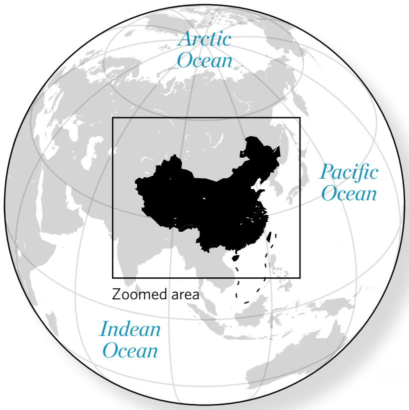
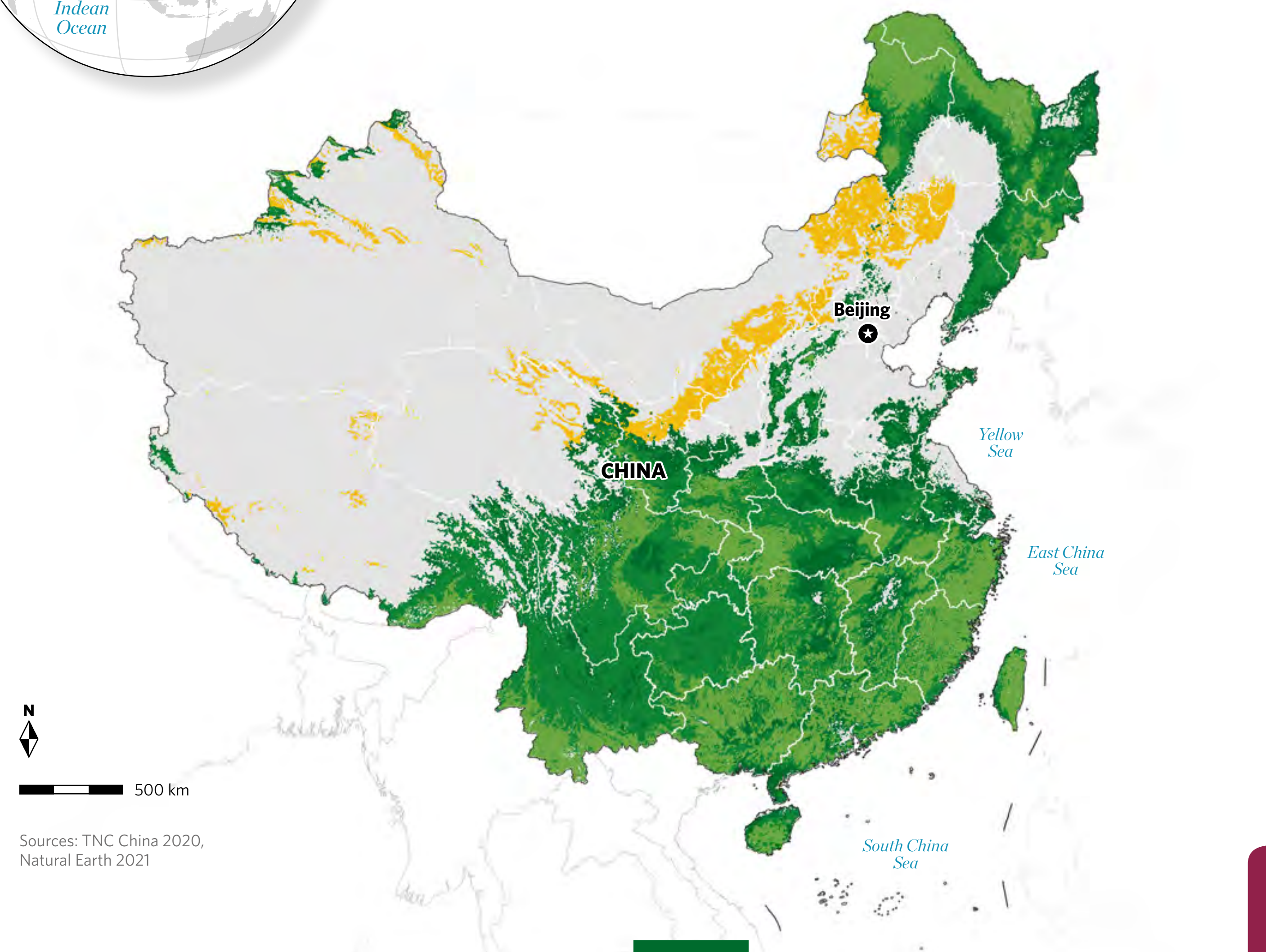
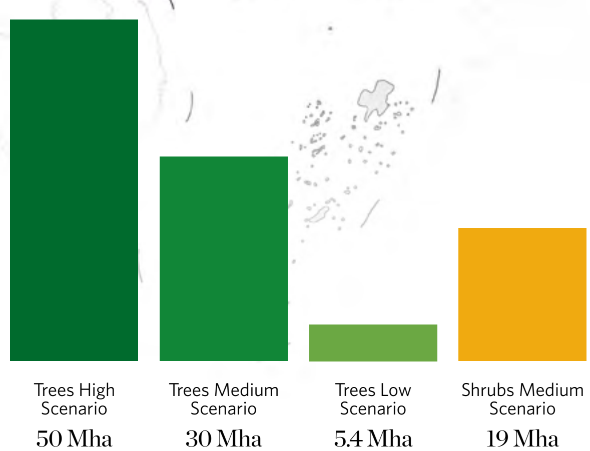


Figure 12: Area of opportunity for restoration and improved management of forests in China (high scenario for trees inclusive of medium and low scenario, medium scenario inclusive of low; only medium scenario shown for shrubs)



Sources: TNC China 2020, Natural Earth 2021



China's GHG emissions have increased fourfold in the past three decades[62]. As the world's largest GHG emitter, China has pledged to be carbon neutral by 2060 through adopting more vigorous policies and measures.

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Nature-based Solutions (NbS) began to enter the Chinese policy context and were widely accepted after China co-led the NbS symposium at the 2019 New York Climate Summit. NbS include strategies that employ nature to tackle climate change, and as such, the China team often uses the term NbS in relationship-building and communication to encompass the team's NCS work. It is easier to get people engaged with the NCS work since they are already familiar with NbS. Additionally, NbS work is connected with several different ministries, including the Ministry of Natural Resources, the Ministry of Ecology and Environment, the Ministry of Agriculture and Rural Affairs, and the State Forestry and Grassland Administration. The TNC China team has been doing NCS/NbS-related work for more than two decades, and therefore was able to build on these existing relationships by using the phrase NbS.

NCS will not be a substitute for reducing energy, industry, and transport emissions, but can complement these efforts to reach carbon neutrality by 2060. With alignment around this assumption, the team engages with a range of stakeholders, publishes scientific articles, and supports outreach and policy development in order to increase impact. With a political window on "green," sustainable, and low carbon development open for the rest of the decade, this provides a solid foundation for strengthening NCS action in China.

BACKGROUND RESEARCH

Several provinces are developing China's 2060 roadmap for carbon neutrality and are providing evidence of NCS mitigation potential. Therefore, to align policy targets with this carbon neutrality pledge, the time sequence of the NCS analysis was set to 2060. TNC and partners held a series of meetings to review relevant NCS public policies in China, including those related to forest, wetlands, grasslands, and agriculture in order to prioritize China's NCS pathways for analysis. To better understand cost-effective mitigation potential of NCS pathways in China, we conducted a literature review focused not only on national and regional studies in China, but on global studies as well. The latest research shows that by the middle of the 21st century net carbon sequestration for the AFOLU sector in China will be about 700 Mt CO_2e per year [63].

TNC global analyses found that reforestation has the largest mitigation potential for the country. Reforestation and improved forest management contribute prominently to China's NDC[64]. President Xi announced that China will increase forest stock volume by 6 billion m^3 compared to 2005 levels by 2030[65], As a result of continued large-scale efforts to add trees to the landscape, additional land suitable for reforestation has been gradually reduced, putting *improved forest management* into a very significant position to contribute to increasing forest stock volume. Meanwhile, in areas of water stress or to prevent desertification, shrubs may be more ecologically appropriate than trees for continued restoration activities.

The total area of the "blue carbon" ecosystem (mangrove, sea grass, and salt marsh areas) in China's coastal zone is 1,623–3,850 km^2[66]. The total carbon sequestration capacity of various types of marsh wetlands in China is 4.91 Mt CO_2e per year[67]. The annual average carbon sequestration of these blue carbon systems is 1.28–3.06 Mt CO_2e per year. However, due to the combined impacts of climate change, reclamation, over-utilization of resources, and environmental pollution, the blue carbon ecosystem is being rapidly degraded in China[66].

NbS incorporates strategies that employ nature to tackle to climate change and as such the China team often uses the term NbS to encompass the team's NCS work.

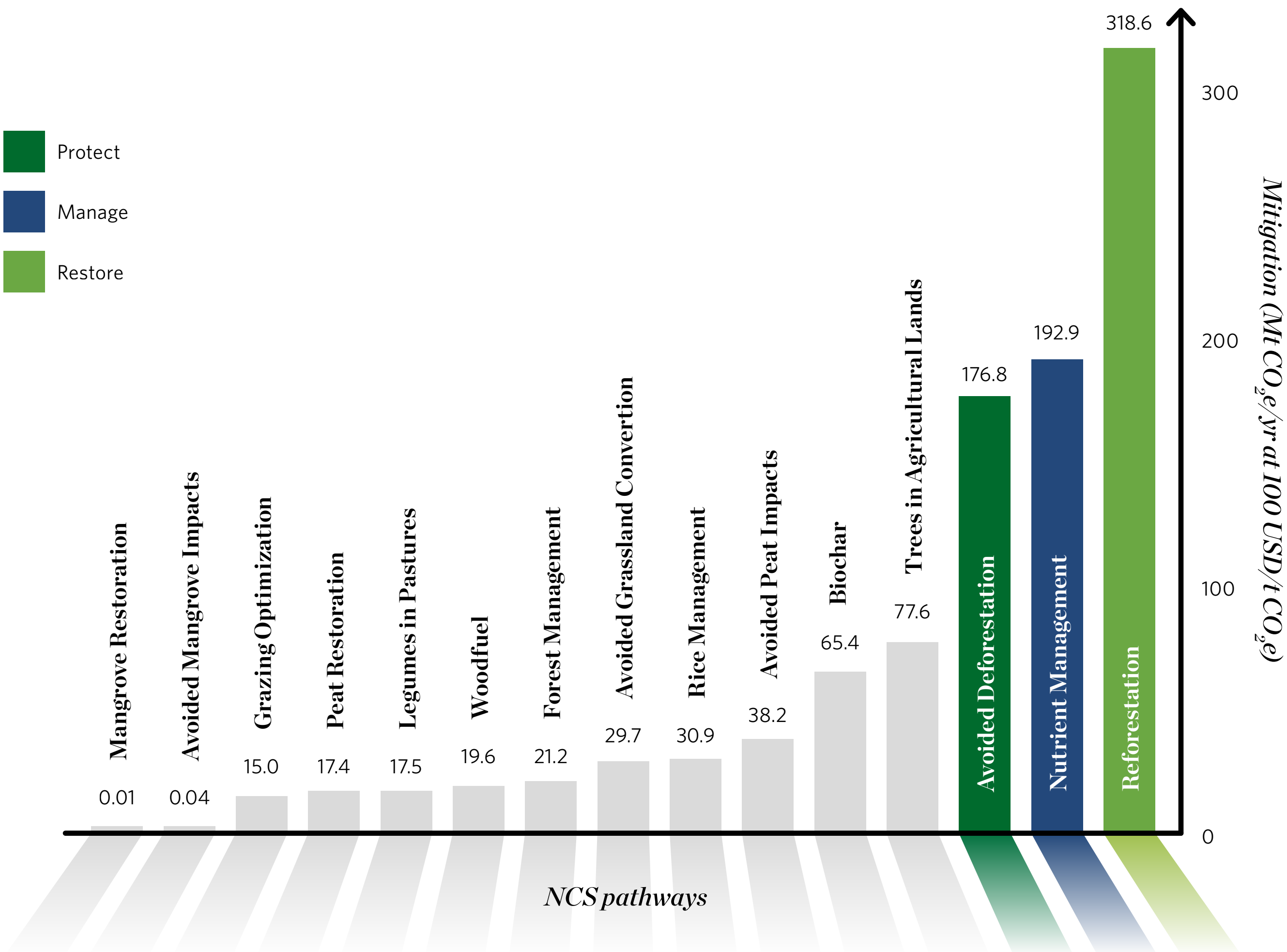

Figure 13: Mitigation potential from China based on global data. Figure adapted from the NCS World Atlas China factsheet

In the past 40 years, China's agricultural output has continued to increase due to high investment. According to FAOSTAT, in 2018, China's chemical fertilizer consumption was 56.5 million tons and the use of nitrogen, phosphorus, and potassium fertilizers accounted for 26%, 19%, and 27% of the total global consumption, respectively[68]. China's grassland ecosystem carbon storage is about 7.5% of the world's grassland ecosystem carbon storage, which indicates large mitigation potential from grassland protection and restoration [69,70]. To reduce GHG emissions from the agriculture sector, China has created a number of rules and regulations. Agricultural emission reduction has been placed in a pivotal position in China's National Program on Climate Change as mentioned in the 12th Five-Year Plan[71] and 13th Five-Year Plan[72] for Controlling GHG Emissions. In China's NDC, actions related to nutrient management are critical to reducing GHG emissions.

After collecting sufficient information from our policy and literature review, we set up informal and formal meetings with experts from government, academic, public, and private sectors. This allowed us to better understand their needs and strategic plans to tackle climate change, and to identify potential barriers and opportunities to promote NCS as a cost-effective option for achieving NDC goals.

Previous page: Reforestation project site in key habitat of the Yunnan golden monkey, China. © Liang Shan/TNC

Misty mountain ridges of Laohegou Nature Reserve, Sichuan Province, China. © Nick Hall/TNC

CHINA'S NCS PATHWAYS

The project team consists of local Chinese TNC staff working closely with TNC global team staff and other global and local partners. Using global data[2,31,50] (*see Figure 13*), the team identified the top three cost-effective pathways that together would reduce emissions by 688 Mt CO_2e/yr: *reforestation*, *nutrient management*, and *avoided deforestation*.

Although global data show high potential for *avoided deforestation* as a mitigation option, permanent forest conversion should be low based on the launch of the China Ecological Conservation Redline[73] that seeks to protect important ecological systems across more than a quarter of the Chinese mainland, so it would be challenging to stimulate much additional action related to avoiding permanent forest conversion. *Reforestation* and *nutrient management* both have a substantial cost-effective climate potential in China. Additionally, TNC China has been working on reforestation and forest management for 20 years, which are complementary and together provide a major opportunity for implementing new reforestation and forest management options. For the above reasons, *nutrient management*, *reforestation*, and *improved forest management* were selected as prioritized pathways for mitigation potential analysis. The China team is working with experts from the Chinese Academy of Agriculture Sciences, Chinese Academy of Sciences, and Chinese Academy of Forestry Sciences to conduct the analysis based on their expertise and influence on the climate change community in China.

LESSONS LEARNED

Establishing strategic partnerships is an important step to build relationships, showcase our work, and influence decision-making processes. To ensure results are seen as credible and are used by decision-makers to enhance NCS implementation, we are working closely with the National Center for Climate Change Strategy and International Cooperation (NCSC) under the Ministry of Ecology and Environment and the Institute of Climate Change and Sustainable Development (ICCSD) under Tsinghua University. Both are important and influential think tanks that provide technical and policy support and recommendations to policy-makers on climate governance.

Publishing articles in mainstream journals is also important for influencing the climate change community in China. In early 2020, we published an NCS paper in the journal *Advances in Climate Change Research*[74]. The findings of this paper were included in internal reference materials circulated in the Ministry of Nature Resources. Additionally, we've completed a book[75] that presents methodologies and best practices related to nature-based solutions interventions.

It is essential to facilitate cross-sectoral cooperation to maximize climate policy outcomes. NCS encompasses multiple ecosystems, policies for which are administered by several ministries, (including the Ministry of Natural Resources, the Ministry of Ecology and Environment, the Ministry of Agriculture and Rural Affairs, and the State Forestry and Grassland Administration) due to the administrative structure in China. To holistically unlock the potential of NCS, both on the ground and at the policy level, the TNC China team is working with key departments under several ministries instead of only those directly responsible for climate change policy.

NCS will be instrumental in helping China achieve its carbon neutrality pledge. As a "no-regrets" approach, NCS are essential for China to achieve carbon neutrality, while simultaneously providing valuable co-benefits for biodiversity, communities, and the economy. China has developed its 14th Five-Year Plan with the next five years being important in determining if China can successfully achieve this pledge. The plan features a new emphasis on "green," sustainable, and low-carbon development, which increases the potential of NCS to contribute to policy design and implementation across all sectors and ministries.

Given the increased public and policy focus on NCS, in the future, TNC will further investigate pathways such as *wetland restoration*, *conservation agriculture*, and *grazing optimization*. This is also a great opportunity to build stronger connections with the agriculture and grazing sectors. More than 60% of total GHG emission come from the private sector, so it is important to engage corporations to enhance NCS interventions. In early 2021, several of China's largest corporations announced beginning the process of carbon neutrality planning, while others committed to carbon neutrality by 2030 and 2040, so it is a good moment in time to activate corporate investment in NCS implementation.

Colombia

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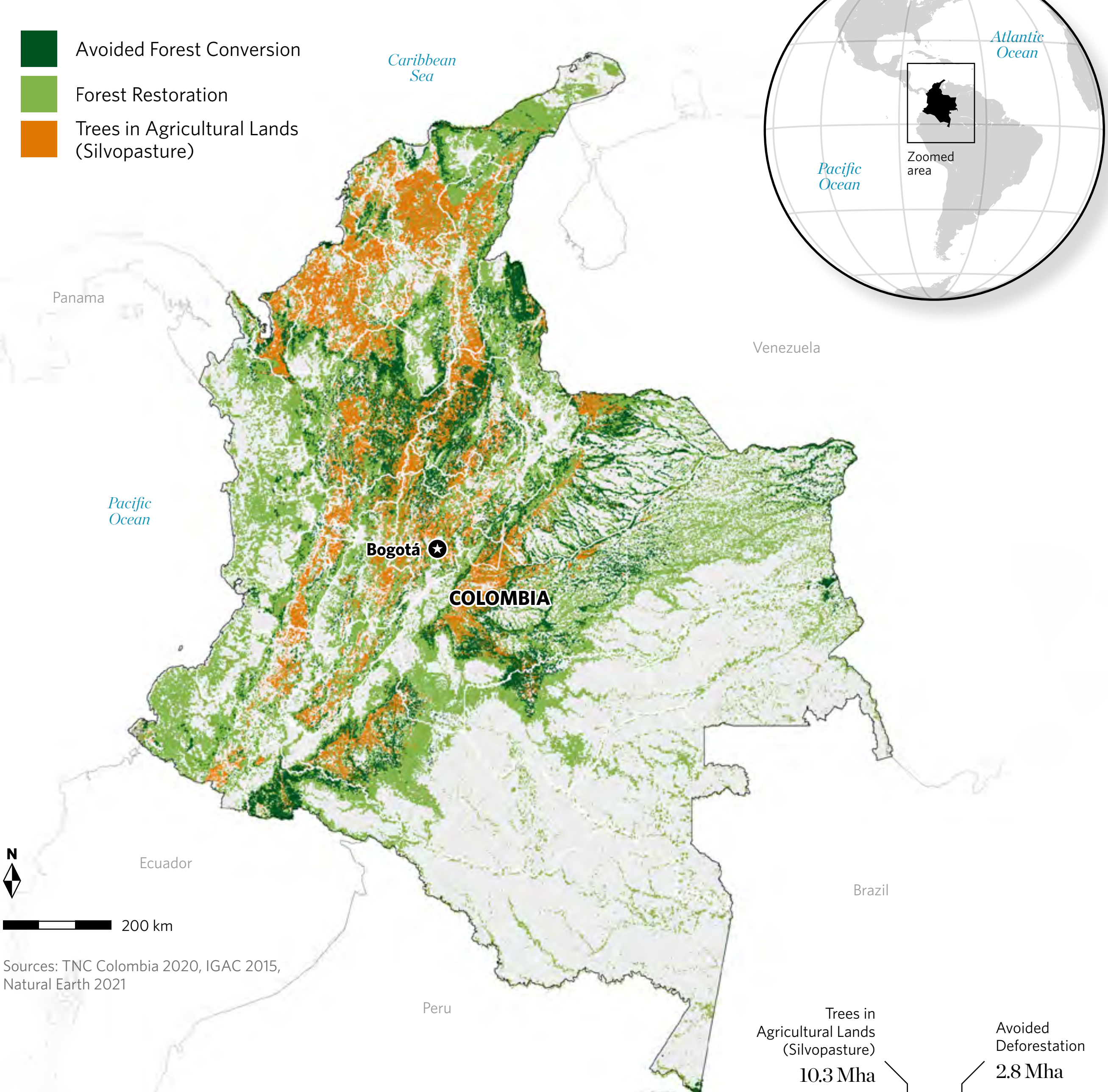
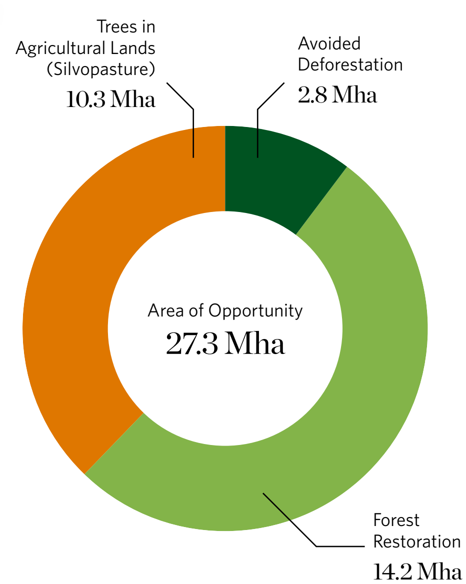
Figure 14: Area of NCS opportunity in Colombia



Preliminary results of the NCS assessment in Colombia show that the maximum biophysical mitigation potential for selected NCS pathways by 2030 is 0.38 Gt CO_2e/yr, of which avoided forest conversion accounts for 34% of the total potential, forest restoration 41%, and trees in agricultural lands (silvopastoral systems), 25%. Draft results were shared with the Colombian government to inform the NDC update process in 2020.



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In a historic decision published in late 2020, the Colombian government increased the ambition of its NDC emission reduction commitment to 51% compared to the 2010 baseline — equivalent to reducing around 169.4 Mt CO_2e annually by 2030. Nearly 75% of this total mitigation will come from measures related to the AFOLU sector including reducing deforestation, restoration, and/or implementing silvopastoral and other agroforestry systems.

Currently, the AFOLU sector in Colombia contributes 62% of the country's emissions (compared with 24% of emissions at the global scale), mainly due to deforestation, forest degradation, and conventional cattle ranching. The high rate of emissions from this sector represents an opportunity to implement actions focused on protecting, managing, and restoring natural ecosystems to reduce emissions.

In 2017, Colombia published the National Carbon Tax, which applies to companies using fossil fuels[76,77]. Currently, the tax is approximately 5 USD per metric ton of CO_2e, increasing annually according to the country's inflation. In the current national context, it is important to highlight that there are two possible options for companies subject to the tax. The first is to directly pay the amount that represents the emissions from using fossil fuels, and the second is to offset the company's carbon footprint through projects developed in Colombia that generate carbon credits, many of which are in the AFOLU sector. For a private company, the voluntary carbon market can provide a flexible option to comply with the National Carbon Tax.

BACKGROUND RESEARCH

Our literature review included scientific papers published in indexed journals, online and physical theses stored in libraries from universities, official reports from the national government, and reports with results developed by TNC as well as other non-governmental organizations and the private sector. We collected recent official reports and maps on deforestation, land suitability, and national restoration plans, as well as country-specific information on carbon content and trajectories associated with business-as-usual land use changes (e.g., deforestation) and NCS alternatives (e.g., forest protection and restoration, silvopastoral systems). In addition, from previous analyses TNC Colombia has developed information on carbon stocks and trajectories for key NCS pathways in the country in order to complement existing information.

We looked for main trends in Colombian public policy aimed at tackling climate change, particularly in the AFOLU sector, and identified potential links to NCS pathways that better contribute to meeting national and international goals. Some of the policies reviewed include the Colombian Strategy of Low-Carbon Development, the Climate Change National Policy, and the Strategy to Control Deforestation and Forest Management, which are associated with the NDC of Colombia and aim to promote a link between economic growth and emissions reductions. Both country- and region-wide programs were considered, such as the National Plan of Restoration or the program Vision Amazonia.

A woman in Colombia involved in the sustainable ranching program cuts timber to be used for fences, furniture, or cattle fodder. © Juan Arredondo/TNC

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COLOMBIA'S NCS PATHWAYS

The team initially identified 13 pathways as relevant in Colombia and refined their definitions to be locally appropriate. We conducted a structured process for further prioritizing NCS pathways for analysis by rating pathways according to several potential criteria as assessed by a number of stakeholders: mitigation potential, government interest, possible co-benefits, data availability, and TNC staff capacity.

Meetings between the TNC Colombia team and experts from academic, public, and private sectors were important for prioritizing NCS pathways, as these meetings helped the team to understand their needs and strategic plans to reduce carbon emissions, and to explore with them potential barriers and opportunities to promote NCS as cost-effective options to meet their emissions reduction goals and support the NDC update process for Colombia.

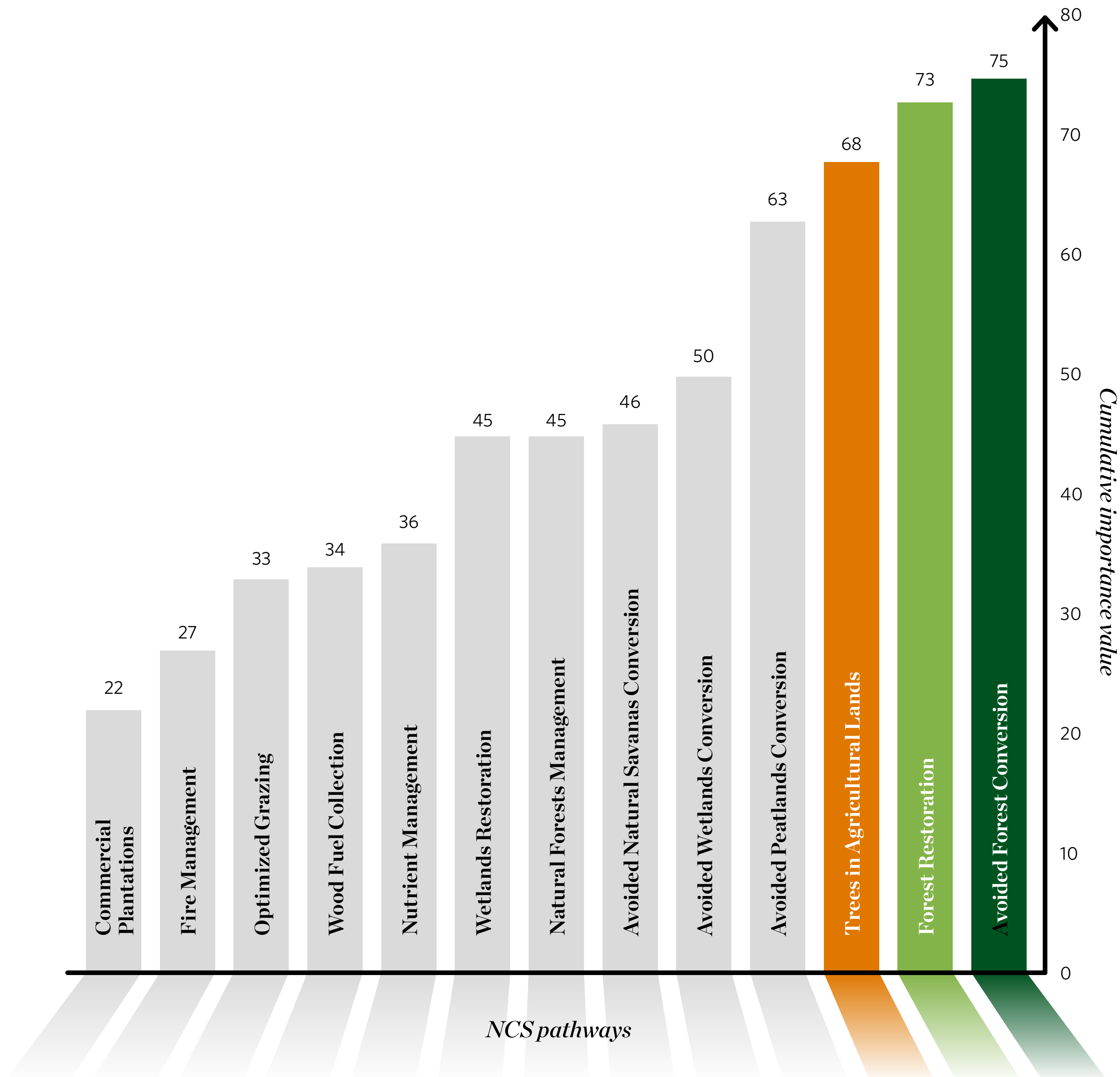

Figure 15: Priority NCS pathways for analysis in Colombia based on comprehensive ratings

From the Colombian public sector, we met with the Ministries of Environment and Sustainable Development, Agriculture and Rural Development, and External Affairs to learn about the government's strategy to update the NDC and to promote NCS as a way to support the update process. We also invited other technical agencies in charge of producing national forest and GHG inventories and deforestation reports, among other relevant information, to participate in these meetings. This helped us understand the availability of official information that could be included in the NCS assessment.

Finally, we met with private stakeholders, including companies from the energy and industry sectors in Colombia who have committed to reduce their emissions. This helped us identify NCS pathways that can contribute to meeting their emission reduction goals and are aligned with their interests.

The three pathways that were prioritized — *avoided forest conversion*, *forest restoration*, and *trees in agricultural lands* (silvopastoral systems) — were rated as having the highest potential to contribute to climate change mitigation and as relevant for Colombia to achieve its recently increased emission reduction goal.

Colombia is the second most biodiverse country per land area on Earth[78], but deforestation, ecosystem degradation, and unsustainable production practices are threatening local biodiversity. Therefore, an accurate analysis of biodiversity co-benefits linked to the mitigation potential of each NCS pathway will help to highlight key areas to protect and restore in Colombia. The TNC Colombia team assessed the habitat and distribution of more than 7,000 species of vertebrates, with an emphasis on threatened and endemic species. This assessment aims to relate the mitigation potential of priority NCS pathways in Colombia with biodiversity indices regarding richness and representativity.

In addition, the TNC Colombia team conducted follow-up assessments of water and social co-benefits, as well as a cost analysis of each NCS pathway at different carbon prices, including the current carbon tax in Colombia (5 USD/tCO_2e). Finally, an analysis of barriers and opportunities to implement NCS activities in the private and public sectors of Colombia provides insights for promoting NCS as catalyzers of carbon markets in the country and as financial alternatives for local communities.

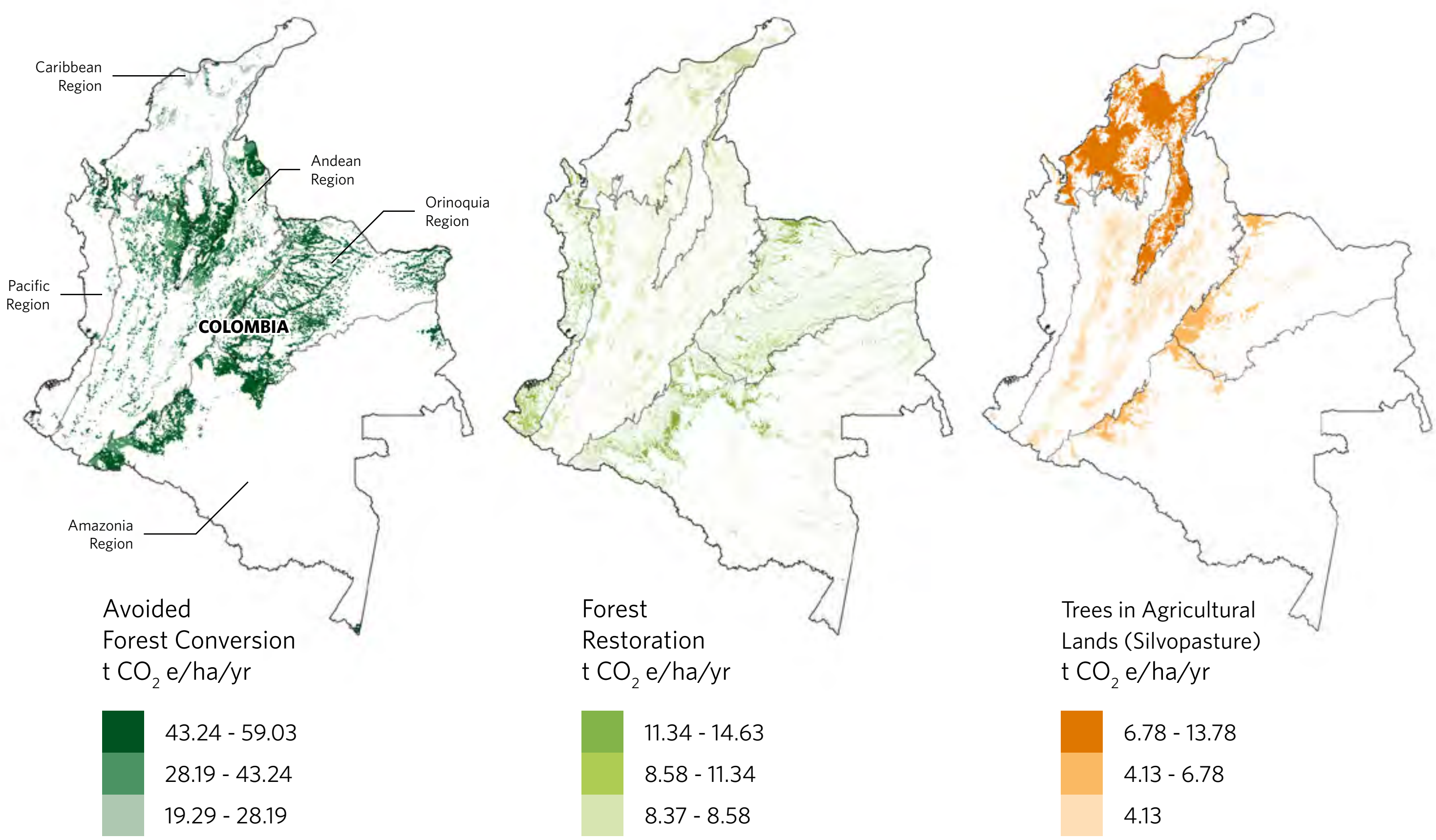

Figure 16: Maximum annual mitigation potential of NCS pathways *avoided forest conversion*, *forest restoration*, and *trees in agricultural lands* (silvopastoral systems) in Colombia for 2030

Sources: TNC Colombia 2020, IGAC 2015

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Beyond mitigation, the TNC Colombia team analyzed biodiversity, water, and social co-benefits to further highlight key areas to protect and restore. Cost analyses at different price points and analyses of barriers and opportunities help to clarify feasible routes to implementation.


TNC Colombia team conducting field training on cocoa crops in the Amazon region, Colombia. © Adrian Rico

LESSONS LEARNED

Colombia has a robust policy and institutional framework for climate change which sets criteria for implementing NCS. However, this existing framework brings with it a set of barriers that affect the implementation of NCS. Barriers the TNC team have identified include:

- High turnover of civil servants impacts the effectiveness of decision-making bodies.
- Inter-institutional and territorial coordination is not supported by budget allocation and personnel, which makes its implementation difficult and reliant on the will and personal capacity of individual civil servants.
- There is neither clear alignment between the planning instruments to tackle climate change and those for land use planning, nor a monitoring system that guarantees the spatial assessment of the programs will be implemented in the country.
- In Colombia, only 37% of rural households are landowners, and of these households only 59% have legal titles.
- There are no simple and standardized metrics to assess NCS effectiveness that work at different geographic scales and that are adapted to the specific intervention contexts. There is also low interoperability among sectors and the regional and national monitoring mechanisms.
- Each sectoral and territorial climate change plan must identify and include the sources of financing required to implement the prioritized measures and reduce excessive dependence on international cooperation resources.
- The municipalities that account for 84% of deforestation in Colombia are also those most affected by poverty, conflict, and weak governance.

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Previous page: TNC Colombia team conducting carbon monitoring research in an Andean forest in the outskirts of Bogotá, Colombia. © Juan Sánchez/TNC

Cattle pasture in San Martín, Meta, Colombia. © Juan Arredondo/TNC

The analysis on barriers and opportunities to implement NCS activities in the private sector of Colombia has shown that:

- The environmental investments or activities that matter the most to the average private company are the ones that affect directly, and in the short term, their core business and finances. This could indicate that the AFOLU and energy sectors are more likely to implement NCS actions.
- The lack of knowledge within financial entities about NCS projects — and their profitability, risks, and types of guarantees — is a barrier for the private sector to invest in NCS initiatives.
- Very few companies or individuals have the capacity to carry out biodiversity and climate change projects on the large scale needed for their effectiveness.
- Land tenure in Colombia is legally weak, which acts as a barrier to carry out many projects and land acquisition.

Actions we consider relevant to overcome these barriers include:

- Contributing to the design of local strategies for land use planning at the landscape scale in those territories targeted to implement NCS.
- Supporting the Colombian government in defining inter-sector strategic agendas and in harmonizing relevant NCS implementation policies.
- Complementing the efforts of land use planning at the local level by adopting a micro-land planning perspective in NCS implementation processes.
- Facilitating spaces for participation that promote territorial planning dynamics in the territories prioritized for implementing NCS.
- Complementing the intervention models associated with NCS income generation schemes that integrate value-chain-strengthening activities with landscape management actions. This is particularly important in municipalities located in deforestation hotspots, which are commonly affected by poverty, conflict, and weak governance.

Indonesia

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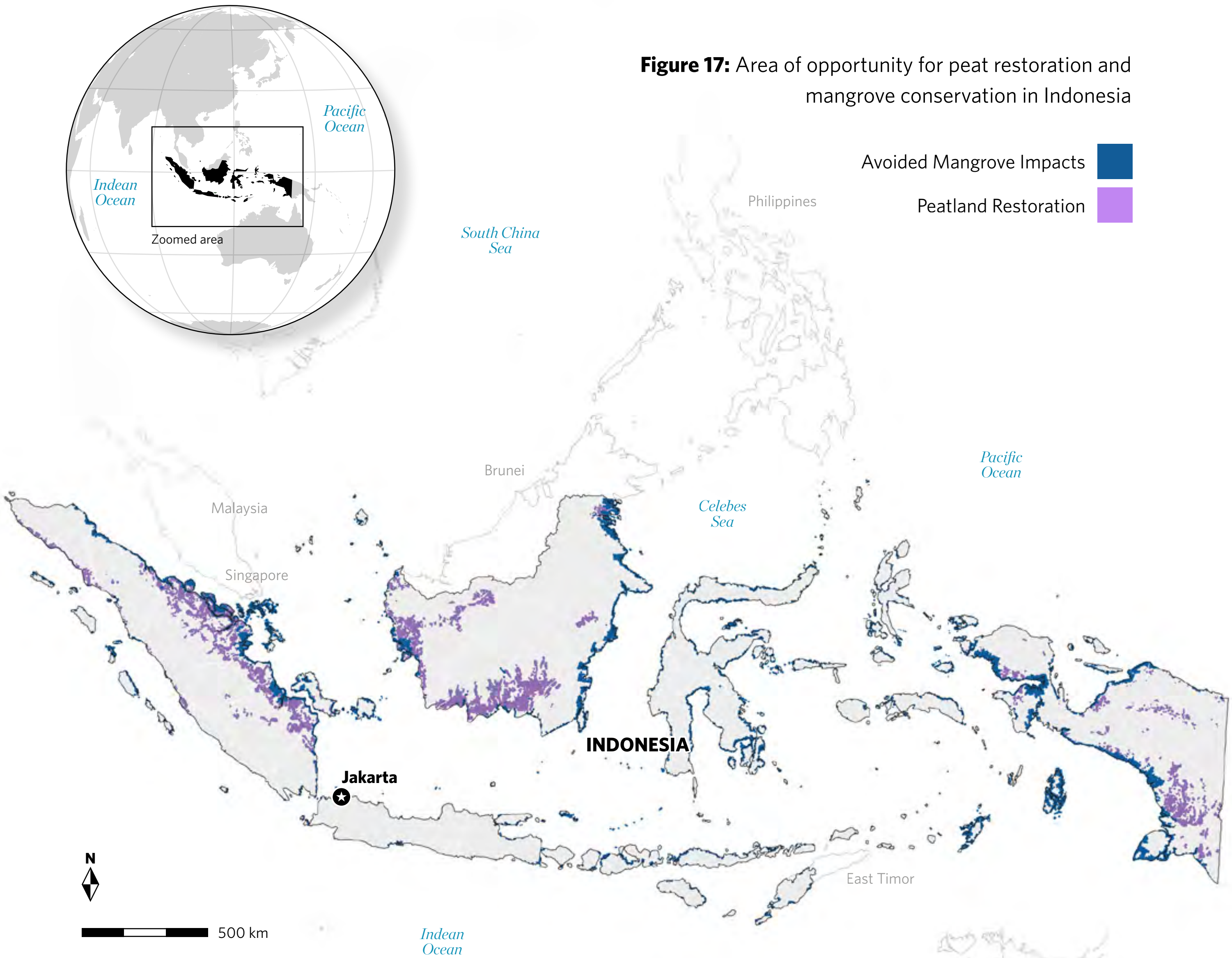
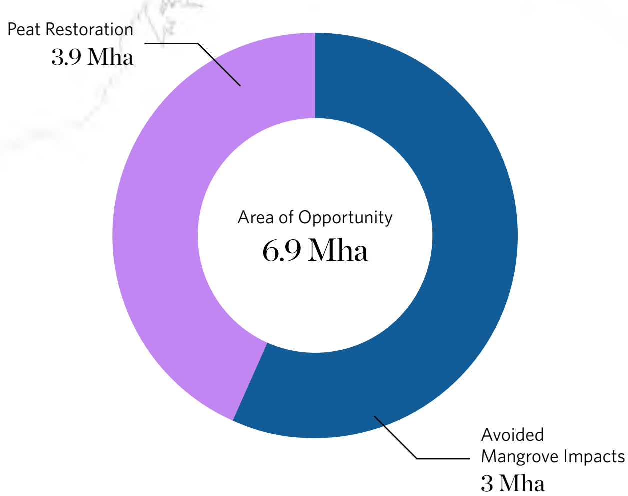
Figure 17: Area of opportunity for peat restoration and mangrove conservation in Indonesia



Sources: Yayasan Konservasi Alam Nusantara *in preparation*, Ministry of Environment and Forestry Indonesia 2019, Ministry of Agriculture Indonesia 2011, Natural Earth 2021



In addition to its diverse tropical evergreen forests, Indonesia is a wetlands hotspot, home to peatlands and mangrove systems which are the most carbon-dense ecosystems in the tropics. While covering a small percentage of the total forest area in Indonesia, wetlands can play a significant role in meeting Indonesia's emission reduction goals.

Fishermen pass through mangrove forests in Langsa City, Aceh Province. © Junaidi Hanafiah/TNC

Indonesia has experienced tremendous economic progress over the last two decades, making the nation the second-fastest growing G20 economy. Indonesia has ratified the Paris Agreement and submitted its first NDC. It has committed to reduce GHG emissions by 29% unconditionally and up to 41% conditionally (i.e., if provided international funding support) by 2030 against the business-as-usual emissions scenario based on the baseline year of 2010. Annual GHG emissions from 2006–2016 averaged 711 Mt CO_2e[79]. The forestry sector is the main source (44%) of GHG emissions in Indonesia in recent years, and is expected to contribute up to 17% (497 Mt CO_2e) of the unconditional target. The major sources of emissions are from the AFOLU sector via peat decomposition, peat fires, and land use change to cropland. Indonesia is estimated to have the highest NCS potential among tropical countries[80].

In addition to its diverse tropical evergreen forests, Indonesia is a wetlands hotspot, home to peatlands and mangrove systems which are the most carbon-dense ecosystems in the tropics. While covering a small percentage of the total forest area in Indonesia, wetlands can play a significant role in meeting Indonesia's emission reduction goals. Indonesia contains 126 million ha of areas classified as forest, of which 45% is designated for conservation and protection, while the rest is designated for production. There are 14.9 million ha of peatlands in Indonesia, which amounts to 84% of peat carbon in Southeast Asia[81] and 18% of peat volume globally[82]. Mangroves cover 3.3 million ha along Indonesia's 95,000 km coastline[83], the largest of any country in the world.

There is a strong possibility that the government of Indonesia will not increase its emission reduction ambition for the current NDC update because the current target is considered high against the backdrop of the nation's economic growth goal. The focus of the government is on implementing strategies to meet its current targets. However, the Indonesian government has not ruled out increasing ambition for future NDC updates. Within this context, an NCS study that includes science, economics, and policy factors could provide insight into where resources could be most efficiently directed. It will also provide a foundation and confidence for future increases in ambition while positioning Indonesia to obtain more recognition and incentives for future emission reduction efforts.

BACKGROUND RESEARCH

The Nature Conservancy and its main local partner in Indonesia, Yayasan Konservasi Alam Nusantara (YKAN), co-organized a national workshop in Bogor in January 2020 to discuss priority NCS pathways in Indonesia for the NCS Indonesia study. The process of selecting NCS priority pathways was undertaken jointly with the Research, Development and Innovation Agency at the Ministry of Environment and Forestry (MoEF), involving policy-makers, influential scientists and research centers, the private sector, and NGOs.

One of the main objectives of the NCS Indonesia study is to provide robust scientific evidence to the government of Indonesia in order to optimize mitigation opportunity and thus support Indonesia in achieving its NDC targets by 2030. Indonesia has received approvals for two REDD+ results-based payments from Norway and the Green Climate Fund as the result of the country's efforts to reduce emissions from deforestation and forest degradation. While the methodology and monitoring system for the *avoided forest conversion* pathway are already quite advanced in Indonesia, improvement for national monitoring for other pathways, for example for *peat restoration* and *sustainable forest management*, is needed.

Indonesia is in the process of updating its first Forest Reference Emission Level (FREL) that was published in 2015. The second FREL, planned to be submitted at the end of 2021, will have two main improvements: 1) the addition of more mitigation actions and 2) the improvement of activity data and emission factors using higher-tier methodology (that is, more complex and accurate based on IPCC guidance[84]) and best available science. The first FREL covers three avoided emissions mitigation actions: deforestation, degradation, and peat decomposition. In the second FREL, the Indonesian government will (most likely) add three more interventions, related to peat fire emissions, mangrove soil carbon, and reforestation. The NCS Indonesia program will provide technical support to the Government of Indonesia for improving GHG accounting methodologies for peat fires, peat decomposition, and avoided emissions from mangroves impacts.

The NCS Indonesia program provides robust science and technical support, such as accounting methodologies for peat and mangrove impacts, to national decision-makers in order to optimize mitigation opportunity and support achieving NDC targets.

INDONESIA'S NCS PATHWAYS

Priority pathways were selected based on current available scientific evidence, mitigation potential, effectiveness of mitigation action, and alignment with national strategy. Seven NCS strategies were prioritized for the NCS Indonesia study: *avoided forest conversion*, *reforestation*, *sustainable forest management*, *avoided peat impacts*, *peat restoration*, *avoided mangrove impacts*, and *mangrove restoration*.

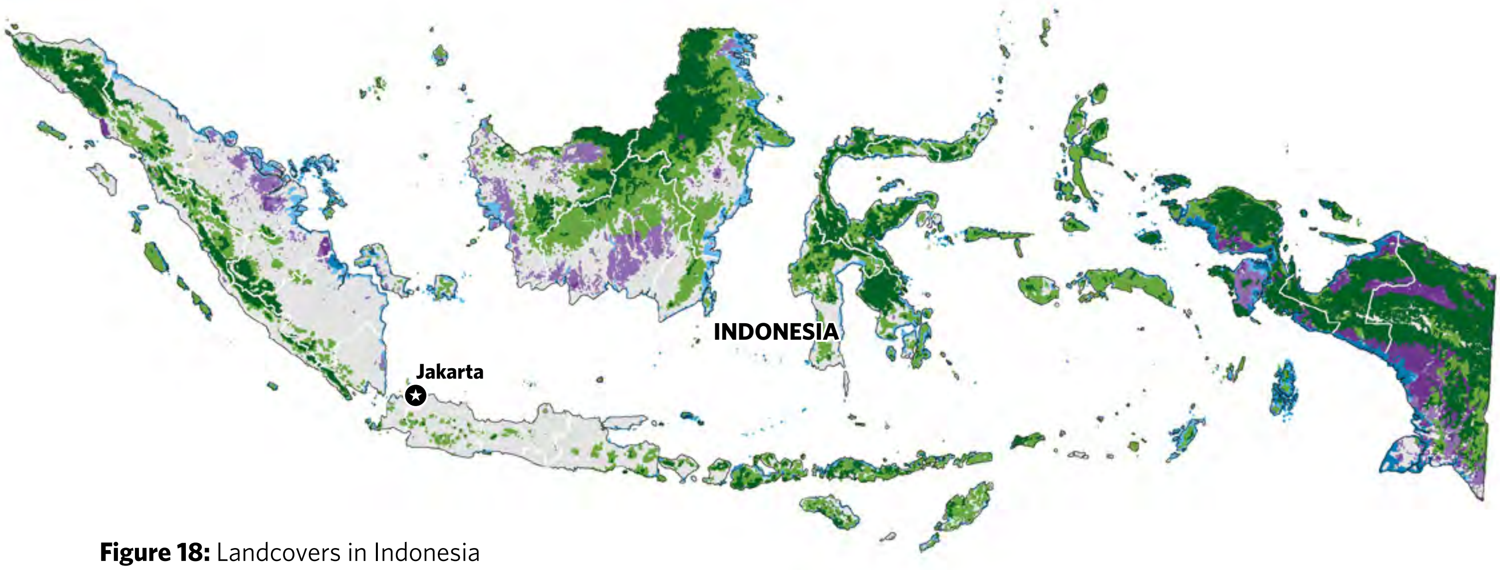


Figure 18: Landcovers in Indonesia

Primary dryland forest
Secondary dryland forest
Primary mangrove forest
Secondary mangrove forest
Primary swamp forest
Secondary swamp forest

Sources: Ministry of Environment and Forestry, Indonesia, 2019, Natural Earth 2021

Peatland mitigation has the highest NCS potential compared to other strategies, and includes avoided deforestation (vegetation loss and peat decomposition), avoided peat fires, and peat restoration through rewetting. Based on our analysis, avoided peat decomposition due to land cover change has the potential to avoid 459 Mt CO_2e/yr, followed by 217 Mt CO_2e of avoided emissions from peat fires. Most peat emissions are from the soil, while vegetation loss only emits 42 Mt CO_2e/yr. Peat restoration is a promising strategy, which has the potential to reduce 205 Mt CO_2e/yr but cannot offset the emissions resulting from land use or land cover change on peatlands. Overall, we have calculated that potential emission reductions from avoiding peatland conversion, avoiding peat fires, and restoration of peatlands is estimated to be 924 Mt CO_2e/yr, which is nearly double the emission reduction target from the forestry sector stated in Indonesia's NDC (497 Mt CO_2e/yr) (*see Figure 19*).

Indonesia has the largest mangrove cover in the world, with estimated ecosystem C stocks reported to be 563[2] and 951–1,083 t C/ha[85,86]. Our analysis found the number to be 1,063447 t C/ha. Through the NCS Indonesia study, our team is compiling a comprehensive and up-to-date dataset that can provide policy-makers with the necessary information needed to determine the values of conservation and restoration with respect to climate change mitigation and adaptation strategies. Previous mangrove estimates from the IPCC (2014)[87] and Griscom et al. (2017) [2] were 2.6 times and 5 times lower, respectively, than Indonesia's recent official estimate. We worked to refine those previous estimates using Tier 2 (intermediate level) data to contribute to improving the official emission factor for mangroves (which is used across the country to estimate emissions from activity-level data). There are limited studies on soil carbon emissions from mangrove ecosystems in Indonesia, but ignoring this significant carbon pool will hinder Indonesia's ability to achieve its emission reduction target in 2030. Soil carbon mangrove is now being considered for the second FREL.

Peat mitigation potential

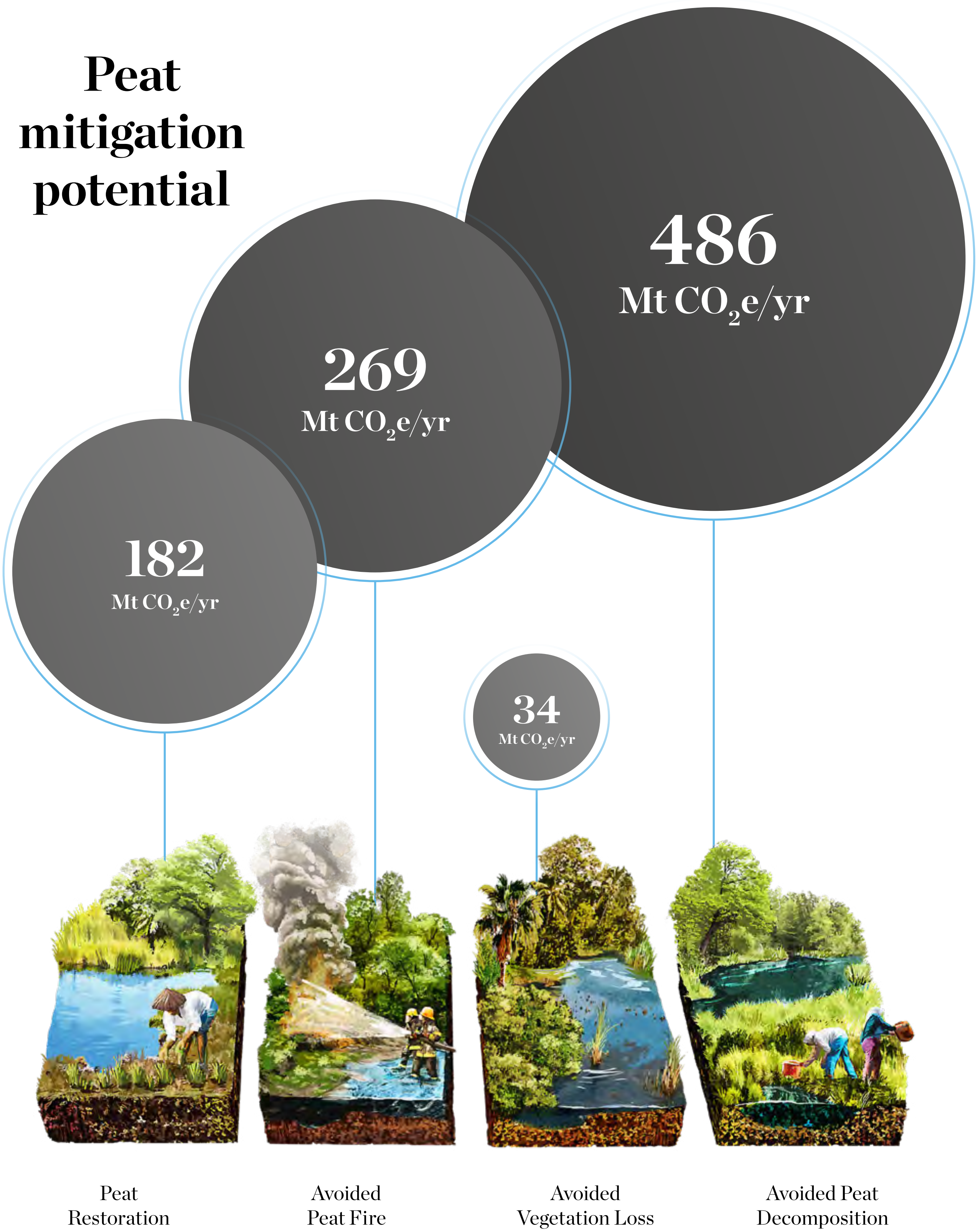


Figure 19: Potential emissions reductions from avoided peat impacts and peat restoration in Indonesia

The NCS Indonesia program provides robust science and technical support, such as accounting methodologies for peat and mangrove impacts, to national decision-makers in order to optimize mitigation opportunity and support achieving NDC targets.

LESSONS LEARNED

Government targets, which will eventually entail allocation of resources, are not only determined by scientific findings, but also by other factors such as politics and sectoral interests. While the value of a scientific study is probably very clear to the scientists, policy-makers will also want to weigh other considerations that will help them in prioritizing deployment of limited resources while gaining the greatest results. Therefore, it is important that such a study also provides added value regarding other considerations that will inform the government's science priorities. On top of providing the scientific analysis that is the focus of the study, the NCS Indonesia study will also analyze economic and policy barriers for implementation.

Climate is often not included as a main consideration for a nation's development, so science that integrates climate and development is an important component for underpinning policy design. Accordingly, the scientific community will need to play an even bigger role in providing the science to inform and guide how these policies are implemented. Economic growth is very important to the government, alongside attracting international investment. It will be important to integrate economic feasibility analyses into the NCS Indonesia study that will demonstrate and capitalize on "win-win" opportunities for climate change mitigation and economic development.

While scientists and NGOs may like to contribute to shaping policies, the reality is that policy-making processes are often not inclusive. Navigating the policy-making landscape is an art that has to be done with engagement at all levels, across technical staff and varying levels of management, in order to ensure effective strategic and timely communication within small windows of opportunity. This approach will provide strong messaging that focuses on the science and how it could be utilized and implemented, which will enhance prospects of being heard and acted upon.

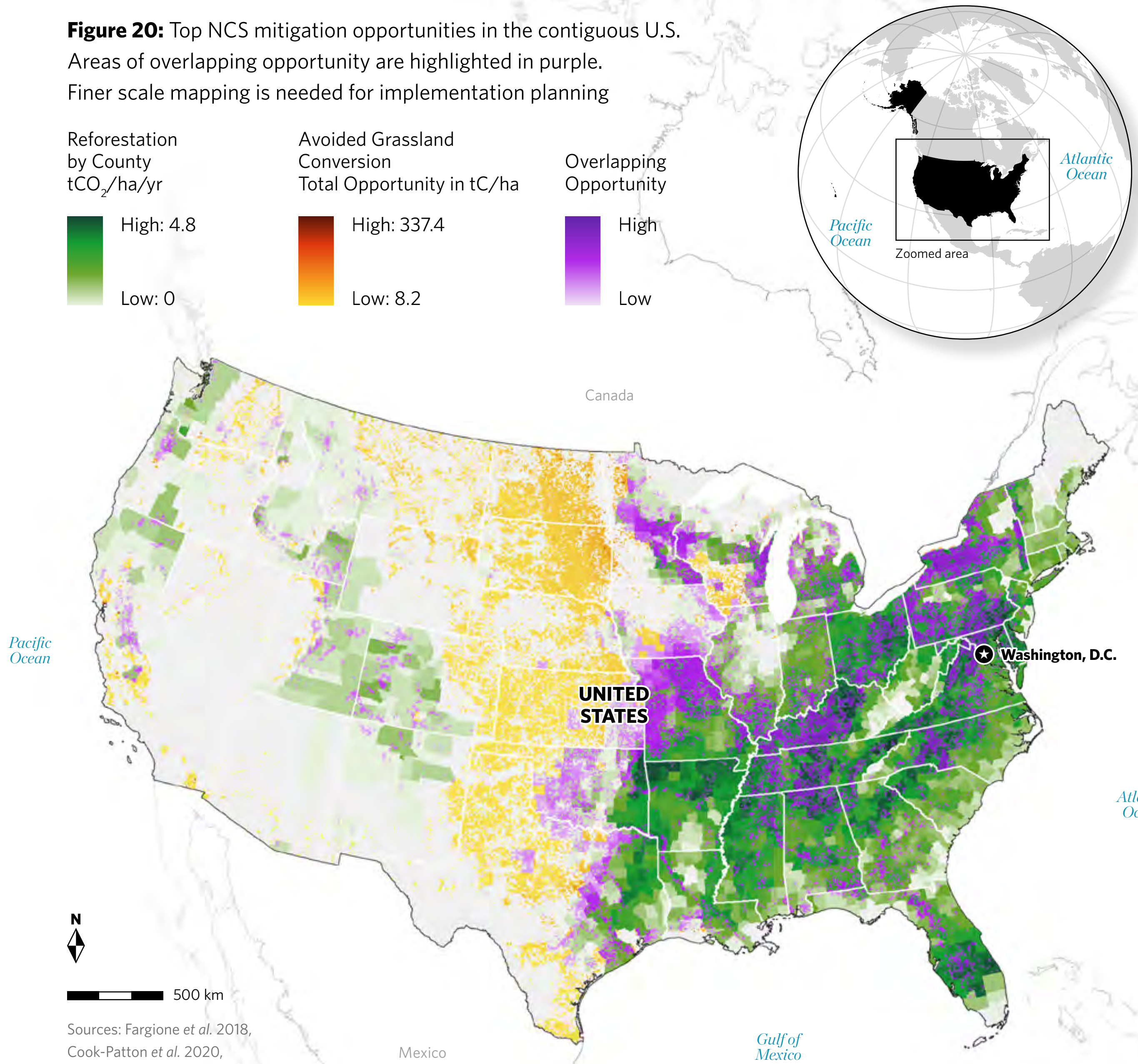
Disseminating our NCS work through a series of meetings and workshops with Government of Indonesia representatives supports the use of best available science by decision-makers. In order to increase public awareness of NCS work and the opportunity for research to support NCS implementation, we also organized national webinars on NCS in October 2020 and on mangroves April 2021. We invited influential speakers, including NCS scientists, national and provincial government representatives, representatives from civil society organizations, and the public. We also regularly update our social media platform (Instagram) for all priority NCS pathways and publish articles related to our peat fire research in reputable magazines and newspapers.

5.

Previous page: Measuring a tree trunk while carbon monitoring in a teak plantation, Berau District, Indonesia. © Bridget Besaw/TNC

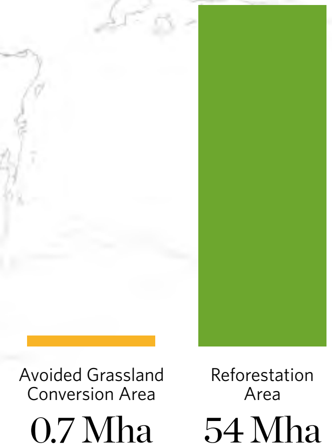
United States

Figure 20: Top NCS mitigation opportunities in the contiguous U.S. Areas of overlapping opportunity are highlighted in purple. Finer scale mapping is needed for implementation planning



Sources: Fargione *et al.* 2018, Cook-Patton *et al.* 2020, Natural Earth 2021

After publishing and disseminating the NCS Global study, we realized that decision-makers needed national-level analyses to inform action. The NCS assessment for the United States[39] represented our first national-level analysis. We were able to utilize the general framework, accounting rules, and safeguards developed in the NCS global study, though we modified pathways to fit the U.S.



A buffer strip along the edge of a field in Michigan, U.S. prevents nutrients and soil from running off the field and entering local waterways. © Jason Whalen/Fauna Creative

BACKGROUND RESEARCH

Our methods generally followed those described in this handbook. We began by convening key experts and identifying the best-available information to include in our study. We then assembled independent research teams for individual pathways. When possible, we included multiple experts on a given topic to build in functional redundancy and ensure thorough and balanced treatment of the topic. For each pathway, we tackled four questions: 1) What is the maximum climate change mitigation potential of NCS in the U.S.? 2) What is the uncertainty associated with those estimates? 3) What proportion of the maximum potential could be achieved at 10 USD, 50 USD, and 100 USD? 4) And what are the co-benefits that NCS can provide?

THE UNITED STATES' NCS PATHWAYS

Though we utilized the framework from the global study, we modified the pathway list and the scope of each pathway to suit the conditions in the U.S. For example, we included an urban reforestation pathway, given the importance of urban greening to many communities in the U.S. We also adjusted the fire pathway so that it focused on large-scale prescribed burning in fire-prone forests to prevent more catastrophic wildfires.

Our final analysis included 21 distinct pathways and represented the first full estimate of NCS potential across the lower 48 states. We found a total NCS mitigation potential of 1.2 Gt CO_2e annually[39]. We found that *reforestation* had the highest maximum mitigation potential, followed by *natural forest management*, and then *avoided grassland conversion*. However, cost-effectiveness changed the rankings; *cover crops* and then *natural forest management* offered the most opportunity at lower costs compared to other pathways. Most of the mitigation potential (63%) comes from increasing carbon sequestration in plant biomass, but 29% comes from increased sequestration in soil, and 7% from avoided emissions of methane and N_2O. Moreover, we estimated that nearly a quarter of the potential can be achieved for less than 10 USD/tCO_2e.

5.

While an analysis of the technical mitigation potential of NCS can reveal opportunities, estimating feasibility of adoption can be even more critical. Breaking this information down to the sub-national level and providing visualization tools for interpretation can have strong impacts on policy-making.

Pannes (pools) in saltmarsh of Lower Kennebec in Maine, U.S. © Harold E. Malde/TNC

LESSONS LEARNED

One of the biggest challenges in conducting the analysis was the unevenness of data. This was a particular challenge for wetlands pathways, which lacked data on methane emissions and net sequestration and how these vary across wetland types. Even with this consideration, data availability and quality for the U.S. is quite good overall. In addition, government decision-makers in the U.S. have tended to be open to considering data from a range of reputable sources as opposed to being constrained by one official source that may or may not match the needs of the analysis.

While conversations on land sector mitigation sometimes focus on the large opportunity in less developed countries, the analysis revealed that the land sector can still make an important contribution to climate change mitigation even in developed countries such as the U.S. The U.S. is the largest cumulative emitter of CO_2 from fossil fuels[88] and remains the second largest annual emitter of GHGs[89]. Despite the immense size of national GHG emissions from fossil fuel use, we found that NCS has the potential to generate mitigation equivalent to 21% of net annual emissions.

Developing sub-national data and visualization tools can have strong impacts on policy-making. In 2018, the paper was published in *Science Advances*, a peer-reviewed and open-access publication. Since then, it has been cited by over 100 scientific studies. The paper garnered the attention of those within the U.S. Congress and the lead author was asked to testify on the results. We also developed a U.S. State Mapper web tool on Nature4Climate.org that provides state-level estimates of NCS potential by pathway and by

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Previous page: TNC staff study mixed Longleaf, Loblolly and, Shortleaf pine forest outside Columbus, Georgia, U.S. © Mark Godfrey/TNC different cost thresholds. These estimates proved to be very useful for informing discussions of the Natural & Working Lands working group of the U.S. Climate Alliance. The Alliance is a coalition of states who are committed to fighting climate change. As a part of this working group, a coalition of NGOs hosted a series of "learning labs," starting with a national lab in Washington, D.C. in July 2018 and continuing with a series of regional labs in 2019. At each learning lab, state-level opportunity assessments were presented. These opportunity assessments were largely based on our national assessment, where it was possible to disaggregate the national results to the state level. We partnered with other non-governmental organizations to develop briefing materials based on our science to bring to these discussions.

Land management administration in the U.S. is fairly decentralized, resulting in a large number of interested parties. Similarly, the size and geographic variability of the U.S. results in a wide variety of opportunity types by state or region (e.g., emphasis on improved forest management in the Eastern U.S., agriculture in the central U.S., and fire management in the Western U.S.). Combined, this has resulted in the need for deep investment in coordination among implementing parties, as well as the need to customize analysis and communication of opportunity at a state-by-state scale, such as through NCS assessments that have been published for California[90] and Oregon[91].

While this study revealed that NCS represent a bigger opportunity in the U.S. than many people had realized, estimating the feasibility of adoption is much harder — and generally more important — than estimating the technical potential. With this in mind, we have conducted additional research to refine our estimates of particularly promising pathways, such as reforestation[92,93], and co-developed websites, such as the Reforestation Hub, to showcase the latest science and case studies of NCS implementation in action. But in general, three years after publication, the paper remains the single best estimate of the potential for NCS in the U.S. and still actively informs discussions about where and how to deploy NCS as a climate solution across the country.

Morning on a salt marsh on the shores of Great Bay in Durham, New Hampshire, U.S. © Jerry andMarcy Monkman/EcoPhotography

Appendix

Cost Estimates

For any NCS assessment, two prices are key to consider: 1) the price at which a project can supply GHG reductions (the full cost per unit GHG), and 2) the price the project can obtain for these reductions (the expected revenue per unit GHG). These factors affect the cost-competitiveness and hence the financial feasibility of a project, both in the present and the future.

FULL PROJECT COST

The full cost of an NCS project defines the price at which the project can supply GHG reductions. It can also be considered the **supply price** of the NCS project. As described in *"Characterizing Costs,"* this cost has three components:

- **Implementation cost** of the NCS project;
- **Opportunity cost,** which is the foregone net benefit of the land use that is displaced by the NCS project (e.g., for *avoided forest conversion* to cropland, the foregone profit from the crops minus the land clearing and site preparation costs that would have been necessary to establish croplands); and
- **Transaction and other overhead costs** required to make NCS implementation possible.

Importantly, project costs can change over time, and therefore so can a project's cost-effectiveness and financial feasibility. For example, an *avoided forest conversion* project could either acquire or rent lands at risk of conversion. If the intended use of the lands is, for example, as pasture for beef cattle, rental payments would be largely determined by the net income the landowners would expect to receive from their cattle — a value dependent on current and expected future beef prices. Given that these opportunity costs are likely to account for a large proportion of the total costs of the project, unless carbon prices are very high, the project's financial feasibility would be sensitive to changes in supply and demand in the beef markets the landowners can access. In other words, if beef prices increase, the landowners will demand higher land rental prices to compensate for higher forgone net income, and the implementation cost of the NCS project will rise over time.

EXPECTED PROJECT REVENUE

The second key price is the price an NCS project can expect to obtain for its GHG reductions (in other words, what buyers are willing to pay per unit GHG), or its **expected revenue per unit GHG**. This price depends on where the demand for GHG reductions comes from (e.g., carbon markets) and will also change over time as demand fluctuates. Because of the inherent uncertainty about future GHG prices, it is important to assess how sensitive the financial and economic viability of an NCS project is to changes in these prices. Note that changes in future GHG

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Previous page: The dense tropical Wehea forest in the Kalimantan region of Borneo, Indonesia. © Bridget Besaw reduction prices are primarily a concern for projects that generate GHG reductions or reduction credits over time; they do not affect projects that sell off their GHG reductions at the outset.

One can assume that overall demand for GHG reductions will increase substantially over time, and that higher carbon prices will tend to increase supply of NCS projects. However, how this will affect the competitiveness of NCS depends on the relative prices and quantities of GHG reductions from NCS and non-NCS sources (including new technological solutions, which are challenging to predict). This may vary across countries and regions depending on the compliance and voluntary markets projects can access. In countries that impose carbon taxes but that allow offsets in lieu of tax payments, prices of GHG reductions effectively compete with the carbon tax rate, at least for GHG reduction demand from sectors subject to the carbon tax. Moreover, each compliance and voluntary carbon market has its own specific eligibility requirements with respect to the type and origin of GHG reductions that can be transacted. This may limit the demand for NCS-based GHG reductions produced in a particular region.

Some degree of forecasting future GHG prices is possible. One approach uses estimates of the expected marginal damages caused by successive additional tons of CO_2e in the atmosphere — the social cost of carbon (SCC). It then compares this marginal damage cost with the marginal abatement costs, or MAC, of available GHG abatement alternatives (in USD/tCO_2e reduced) to identify the economically optimal amount of GHG abatement: the level at which the cost of the next unit of GHG reduction exceeds the damage caused by that additional unit (*for an introduction to MACs, see "Incorporating Costs: Marginal Abatement Cost Curves" on pages 45–47*). Using this approach, any GHG abatement with a MAC equal to or less than the SCC would be considered worthwhile. Estimates of the domestic SCC have been published for most countries[94], and many countries or sub-national jurisdictions have adopted specific SCC values for domestic policy analysis. Alternatively, predictions of future GHG prices can be based on published estimates (such as those by the IPCC) of what it would cost (per USD/tCO_2e reduced) to implement particular GHG reduction targets.

DETERMINING PROJECT FEASIBILITY

An NCS project can only be financially feasible if the price that can be obtained for the resulting GHG reductions is greater than what it will cost to produce those reductions. As an example, if an NCS project has overall average costs of 30 USD/tCO_2e, and the prices it can obtain for the GHG reductions it produces range from 35–45 USD/tCO_2e, then the project is financially feasible. If the prices it can obtain for its GHG reductions were to drop to 25 USD/tCO_2e, the project would no longer be financially feasible overall because its costs would exceed its revenues. Yet, subunits of that overall project may still be profitable. For instance, a large reforestation project for which costs vary in space because of different land prices paid in different areas might have subunits whose costs are below 25 USD/tCO_2e. Those subunits would still be financially feasible.

Even under GHG prices too low to make a project ***financially* feasible**, it would still be ***economically* desirable** from a societal perspective if the total benefits, including the climate damages it avoids together with other ecosystem services the project produces and for which it does not receive payments, exceed the project's costs.

In the end, actual deployment of an NCS project will likely also be limited by technical, social, institutional, and policy or regulatory constraints, often far below its maximum biophysical potential. While it may be possible to address many of these often poorly understood constraints, doing so can require multi-pronged, location-specific intervention strategies, which will increase GHG reduction costs, take time, and often be beyond the ability of any individual NCS project to implement.


Rancher in Montana, U.S. As a part of the Montana Grassbank Project, parts of the Matador ranch were leased to neighboring ranchers suffering from severe drought in exchange for their participation in conservation efforts. © Ami Vitale/TNC

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Co-Benefits

Implementation of most NCS pathways offers other benefits beyond climate change mitigation, frequently termed "co-benefits".

Mitigation benefit occurs at a global scale, whereas the co-benefits of NCS activities are generally more localized. When speaking with people implementing NCS, we have found that these co-benefits are often what motivate action.

For that reason, it can be very important to track the co-benefits, also sometimes called ancillary benefits, associated with NCS implementation. We have adopted this approach in our NCS Global, U.S., and Canada assessments, and summarize our results here. We have organized co-benefits into five general categories: biodiversity, soil, water, air, and social[2,15]. The examples we mention are by no means comprehensive and there are other potential co-benefits. For instance, climate change adaptation and ecosystem resilience are important benefits which cut across these categories and are supported by many NCS pathways. Moreover, realization of potential benefits is not universal and will depend on how NCS implementation occurs.

Fishing in Smoke Hole Canyon, West Virginia, U.S. © Kent Mason/TNC

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Fall color along the Blackbird Knob Trail in the Dolly Sods Wilderness, West Virginia, U.S. © Kent Mason/TNC

CO-BENEFITS OF FOREST PATHWAYS

Biodiversity. Continuous primary forests conserve biodiversity. Reducing impacts of logging, extending harvest rotations, managing fire to mimic historical fire regimes, reducing harvesting of woodfuel, or planting wildlife corridors and buffer areas can enhance biodiversity conservation.

Soil. Forests can improve soil water retention and flow regulation and maintain soil biological and physical properties, ensuring the continued health and productivity of forests. Reforested sites often show a measurable increase in soil fauna. Forests with lower-severity fires (instead of catastrophic wildfires) have more organic matter, improved soil properties, faster recovery times, and better water infiltration and retention.

Water. Forests can improve availability of water for crop irrigation and drought mitigation, avoid sedimentation for hydroelectric dams, protect nearby freshwater ecosystem integrity, regulate flooding, and enhance water infiltration and retention.

Air. Forests are important for ozone abatement and air filtration. Better fire management can reduce particulate matter, and more efficient cookstoves improve indoor air quality, both of which can improve quality of life and reduce human mortality.

Social. There are cultural, aesthetic, recreational, and spiritual benefits to conserving forests. As such, their conservation tends to have strong public and stakeholder support. Forests are home to many Indigenous communities worldwide. If implemented appropriately, reforestation can lead to increased employment opportunities and an increase in socioeconomic benefits for forest-dependent communities.

CO-BENEFITS OF WETLANDS

Biodiversity. Protecting or restoring coastal wetlands maintains wildlife habitat, including nurseries for commercially important fish and shrimp. Protecting or restoring peatlands protects diverse ecological communities, including many distinctive insects.

Soil. Coastal wetlands provide protection for coastlines and cross-system nutrient transfer to coral reefs.

Water. Coastal wetlands, peatlands, and mangroves all provide various services related to water filtration, flood control, and storm water remediation.

Air. Restoring peatlands and/or avoiding peatland impacts can decrease peat fire risk, thereby reducing exposure to pollutants that can cause lung and pulmonary disorders. Tree planting helps capture airborne particles and pollutants.

Social. Mangroves serve as habitat for commercially important fish, thus contributing to food security, livelihoods, and human well-being. Salt marshes and seagrass beds provide habitat for plant species important in artisanal harvests as well as waterfowl harvested by subsistence and recreational hunters. These habitats are valued for tourism, recreation, education, food security, and household income. Peatlands provide food sources for Indigenous and other local communities, including hunting and foraging.

Sunset over the still waters of the National Key Deer Refuge, Florida, U.S. © Kyle P. Miller/TNC

CO-BENEFITS OF GRASSLAND AND AGRICULTURE PATHWAYS

Biodiversity. Protecting grasslands sustains important habitat for nesting and foraging birds. Fertilizer management supports fish species richness and abundance by reducing nutrient runoff into waterways. Trees in croplands can provide habitat for species and support ecosystem connectivity. Improved grazing management reduces disturbance to plant-insect interactions. Legumes can increase insect diversity.

Soil. The addition of biochar enhances soil quality and fertility in temperate regions. Better nutrient management helps maintain soil fertility. Trees in croplands can provide erosion control. Grazing management can improve soil's ability to trap contaminants and other sediments. Legumes improve soil structure and fertility.

Water. Grasslands can provide flood control and maintain ecosystem water balance. Cropland nutrient management improves water quality, which can have positive impacts on drinking water, habitat, and recreation. Conservation agriculture, improved grazing practices, and improved rice cultivation reduce agricultural water demands. Trees in croplands can provide water recharge.

Air. Improved nutrient management can reduce nitric oxide and other emissions. Tree planting helps capture airborne particles and pollutant gasses. Avoided burning of crop stubble and reduced tillage reduces damaging particulate matter exposure.

Social. Sustaining rangeland and ranching can support cultural heritage and rural tourism. Growing and processing cover crop seeds can lead to increased employment opportunities. Legumes can improve grazing quality which increases efficiency of livestock. In some places, grassland fire management may preserve farming and cultural practices of Indigenous Peoples.

We quantify biodiversity benefits following the definitions set by the Convention on Biological Diversity[95]; and other benefits as defined in the Millennium Ecosystem Assessment[96]. The Millennium Ecosystem Assessment provides a good starting list, but we recommend talking to impacted stakeholders to determine the benefits that they most want to see.

For some NCS analyses, it may be useful to conduct detailed analyses of where and how NCS can best optimize co-benefits. For example, in the U.S., we were particularly interested in locating areas where we could achieve both climate change mitigation and flood regulation benefits. To do this, we developed 30-m resolution raster maps that identified areas suitable for reforestation and which also fell within zones that flood approximately every five years. We focused on these locations after conversations with state-level practitioners revealed that local stakeholders were most interested in planting trees to gain water benefits.

Carbon Offsets

Carbon offsets represent a reduction or storage of GHG emissions made in order to compensate for emissions elsewhere.

They are one of the many strategies that can be used to reduce or store GHG emissions using NCS, along with other pay-for-performance programs, payments for ecosystem services programs, or results-based finance through multi-lateral or bi-lateral donor aid.

There are two types of offsets markets at present: **compliance offsets** (where companies are required to meet a cap or pay a tax on emissions, and can buy offsets through a regulated market to help meet these obligations), and **voluntary offsets** (where anyone can purchase offsets, primarily to meet voluntary climate targets, and as such the price per metric ton of carbon often varies more widely than in compliance markets). Offsetting is only one part of a broader suite of tools needed to achieve credible emission reductions targets. Accordingly, offsets should only be pursued in the context of both ambitious long-term targets and implementation of the mitigation hierarchy (*see "Prioritizing Pathways" page 22*).

While offsets can help attract finance and defray the costs of emission reductions needed to meet a climate target in the short-term, ultimately, all countries and corporations must decarbonize if the world is to limit global temperature rise. Pairing immediate offsetting opportunities with stringent long-term targets will ensure that reliance on offsets will decrease over time. If offsets are part of the funding mechanism for the NCS actions you have analyzed, it is important to consider the following principles. Collectively, these principles help ensure that offsets are being used appropriately and are providing real and lasting carbon benefits:

Context: Are offsets the only way that natural and working lands are considered in your geography's climate plans and policies? If so, use caution. While offsetting can play a role in encouraging restoration, improving management, and avoiding conversion, comprehensive plans and policies must be enacted in order to maintain the existing sink (which is not *additional* for offsets) and to shift the entire sector onto a low-carbon pathway (which offsetting cannot accomplish alone).

Additionality: Does the offset project result in business-as-usual mitigation, or does it go above and beyond what would otherwise be expected? Offset projects are only viable if the supply would not have occurred but for the incentive offered by the purchaser. If a country seeks to incentivize farmers, foresters, and communities (especially Indigenous Peoples) who have historically sequestered carbon or avoided emissions through their usual activities, that should be done separately from an offsetting mechanism. Note that some additionality requirements do not apply to countries seeking to transform the entire land sector through national or sub-national scale REDD+ approaches.

Baseline: What are the historical emissions for the NCS activity? How likely is it that these emissions would continue under business-as-usual activities?

Does the NCS project represent an improvement from what would have otherwise happened? This is a key part of defining additionality and should include a credible starting date and projection of what was likely to happen in the absence of offset funding. Again, differences in calculating baselines will be allowed for national or sub-national scale REDD+ approaches which access very different datasets than on-the-ground projects.

Requirements for buyers: For offsets sold in a regulated market, the state controls the parameters over which companies can purchase offsets and whether there is a limit to the number and types of offsets purchased. In contrast, in a voluntary market, there are no restrictions on buyer access to the market; instead, there are best practice recommendations like utilizing the mitigation hierarchy. Additional regulation may be useful to require company reporting on their emissions and targets in-country, so that there is more transparency about the use of voluntary offsets in this context.

Permanence: Will emissions avoided or removed from the atmosphere stay out of the atmosphere long term? For example, is there reasonable assurance that land used as an offset will remain protected and intact after the project ends? Existing carbon offset standards require permanence across various timeframes. For example, under California's Air Resources Board, forestry projects must ensure permanence for 100 years, while many of the methodologies approved under the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) require permanence of 40 years. The timeframe is influenced by both political and legal circumstances in each location.

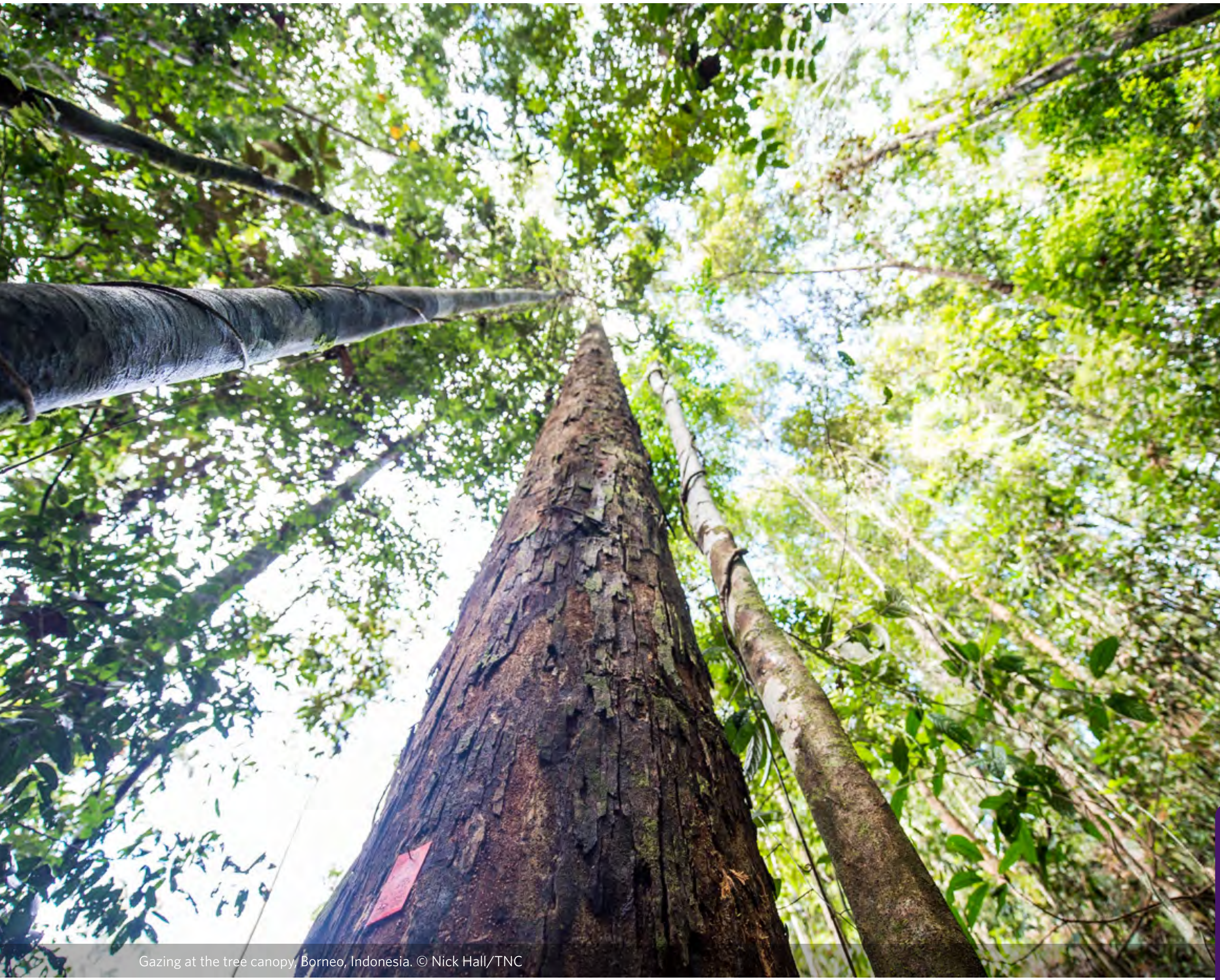
Leakage: Will the avoided emissions be shifted elsewhere? If so, can this leakage be prevented? Leakage is difficult to quantify and challenging to measure. As such, many protocols require projects to apply a standard discount to the total volume offsets generated. For example, an improved forest management project that reduces wood production might have to apply a percent discount to the resulting carbon offsets. That's because, if demand for wood remains the same, there is a strong likelihood that additional wood will be harvested by a different supplier outside of the project boundary.

Measurement and monitoring: How will you measure the emissions reduced or carbon sequestered over time? How often will you monitor? How accurate must measurements and monitoring be? These approaches can include a reliance on technologies such as satellite imagery, LiDAR, and more, but often also includes the need for in-person field measurements. Countries must identify the appropriate balance of the costs of these various approaches with their accuracy — and realize that costs, especially for technological approaches, may improve over time.

Validation and verification: Who is generating the offsets and are they trustworthy? Carbon offset standards will often require the use of a third party to validate the project approach and measurements.

Societal impacts: It is important for providers and purchasers of offsets to consider who might be helped or harmed by these projects. In the case of air quality, for example, communities near an NCS offset project may benefit from improved air quality, while communities near the buyer will remain impacted by negative air quality that might have been reduced if the buyer reduced its own emissions. These trade-offs must be considered when allowing offsets. Additionally, the potential for negative impacts from a project must be identified and avoided. Ultimately, countries must consider if these positive and negative impacts are equitable in their distribution. *See Appendix: Climate Justice*.

Existing voluntary and compliance carbon offset standards often try to address all of these criteria, but may do so to varying degrees due to differences in priorities and available resources. Before allowing the use of any particular standard, it is important to conduct due diligence around that standard's requirements and whether they are appropriate for your situation.



Gazing at the tree canopy, Borneo, Indonesia. © Nick Hall/TNC

Climate Justice

"... climate justice is the fair treatment of all people and the freedom from discrimination in the creation of policies and projects that address climate change as well as the systems that create climate change and perpetuate discrimination."[97]

Climate justice frames our perspective on climate change to include human rights and environmental justice. It enhances our understanding of mitigation to include more than what can be measured in tons of CO_2e. For many people, climate is a matter of life and death, not in some distant future, but in the present. Vulnerable populations including coastal communities, Indigenous Peoples, women, people living in poverty, the elderly, young people, people with disabilities, and other marginalized communities who contribute the least to the climate crisis but often bear the greatest costs and are the first to experience the impacts[98]. Decisions about where to act and which NCS pathways to deploy, as well as how to fund them, are inherently questions of justice and fairness. Climate justice is a critical component to integrate into any analysis that will affect climate policy.

Sound data and rigorous science are essential for conducting an NCS assessment, and climate justice should be considered just as essential. Thus far, climate justice has not been fully and explicitly integrated into the NCS framework, but the authors of this guide recognize that it will be key to ensuring the long-term success of NCS and commit to move in this direction. For example, during background research for an NCS assessment potential rightsholders and other stakeholders should be identified. When mapping political boundaries, customary land use and nomadic groups should also be considered. The LandMark web platform provides information on the lands and natural resource rights of many Indigenous and community groups across the globe.

The NCS framework was built to include safeguards against harm to people by maintaining food and

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wood fiber production levels. Likewise, NCS assessments should ensure that the focus of protecting, managing, and restoring natural systems includes respect for the self-determination of the communities who rely on those lands the most. At a minimum, NCS should not be implemented in a way that will make existing inequities worse. At their best, NCS actions will be designed to improve existing climate inequities by reducing social, economic, and environmental vulnerabilities; generating multiple benefits; and equitably balancing trade-offs. For example, the Tuungane Project in Tanzania takes a 360-degree approach to tackling interconnected health and environmental challenges. The project, a collaboration between TNC, health services organization Pathfinder International, and local communities, supports community and cultural resilience, microfinancing programs, reproductive health services, girls' education, healthy fisheries, climate smart agriculture, and forest management programs that provide sustainable income opportunities through carbon credits from forest protection[99].

The first step towards integrating climate justice is bringing everyone to the table for truly inclusive and equitable climate change and NCS conversations. Countries should create ways to open dialogue around climate commitments and plans with a broad set of rightsholders and stakeholders, including state and local representatives, civil society, Indigenous Peoples, and other local communities. This can be done by using existing multi-stakeholder forums, such as REDD+ engagement platforms, or by creating new spaces to bring voices to the process. Similarly, broad societal participation is a key factor in the political success of NCS implementation, and the NCS assessment process should engage all rightsholder and stakeholder groups to make informed decisions about each geography's assessment and context. It is especially important to include vulnerable populations who have been historically kept out of the global conversations addressing climate change. Conversations with Indigenous Peoples should be guided by principles of free, prior, and informed consent to affirm the self-determination of Indigenous Peoples[100,101]. Furthermore, the autonomy of Indigenous Peoples over their culture, identity, development priorities, self-government, and protection from undue influence by dominant society should be affirmed[102]. Special attention should be paid to avoid gatekeeping and ensure that engagement is an open, equitable process, and organizers are not selectively inviting certain rightsholders and stakeholders while excluding others who may have been silenced or ignored in the past. Additionally, power dynamics should be assessed when convening a diverse group of stakeholders to ensure equitable conversations (examples of how to conduct a power analysis[103,104]).

Some key questions to consider related to power dynamics include:

- *Who sets the agenda? Whose ideas, perspectives, and values dominate the agenda?*
- *How do formal institutions distribute costs, benefits, and accountability?*
- *How are informal social networks influencing conversations and decisions?*
- *Are stakeholders' resource, time, and capacity limitations being considered, and are stakeholders compensated equitably?*

Climate change is not gender neutral[105,106], and solutions shouldn't be either. Integrating gender considerations in climate solutions can prevent further exacerbating existing inequities that make women disproportionally vulnerable to climate impacts such as disease and natural disasters, which supports the SDG of gender equality[107]. For instance, Terry (2009) asserts that there is no climate justice without gender justice and that gender analyses are essential to evaluate polices to reduce carbon[105]. The UNFCCC also recognizes that effective climate solutions require an understanding of gender inequities and their intersection with issues including institutional structures; access to and control of resources; decision-making processes; and social, cultural, and formal networks[108]. In sum, gender analyses illustrating the interactions between climate change and gender inequities are essential to ensure climate solutions are gender responsive and transformational.

Secure land and resource rights are essential to life, livelihoods, resilience, and security. Sixty-five percent of the world's lands are managed by Indigenous Peoples and local communities under customary land tenure, but only 10% of these lands are formally recognized by states as owned by these groups[109]. These lands often provide a substantial carbon sink, which countries can claim as part of their progress towards meeting their climate targets. While carbon mitigation from the historical conservation of these lands is not *additional*, continuing protection of these areas is essential for keeping global temperature rise well below 2°C, and thus should be rewarded and incentivized. Furthermore, land claimed by local communities that was previously colonized could be returned to traditional owners to reintroduce land and fire management practices that may yield climate change mitigation results[110].

Control over land is a major source of conflict that threatens human rights, economic development, culture, conservation, and climate change mitigation[109]. Companies with strong political connections and wealth are often able to secure land rights quickly while Indigenous Peoples and local communities spend years navigating complicated and burdensome processes to obtain them. Many existing NCS projects have helped clarify land tenure for local landowners and communities[111], but institutional problems must be addressed at scale to truly transform the land sector. Several NCS projects that operate next to or within protected areas have found that even though areas are officially "protected," nearby communities still rely on the land to live, and thus continue with activities that result in deforestation and/or forest degradation to meet their needs. Furthermore, in many cases, areas delineated as protected areas often block local communities from using the land to sustain themselves while companies and governments may still profit off of it. Considering the historical inequities and injustices that surround land rights is critical when conducting an NCS assessment.

Some key questions to consider related to control over land include:

- *Who owns the land that is being considered for NCS activities? Who has rights to the land?*
- *Were communities displaced and/or disenfranchised from this land?*
- *Will land rights inequities be improved or worsened through NCS implementation?*
- *Could you include securing land rights as a climate change mitigation solution in your assessment?*

Each country's climate justice context is unique. One NCS assessment technique may not apply for all countries in terms of ensuring climate justice. Throughout your analysis, it can be difficult to make the connection between an analytical decision (e.g., what land cover resolution to use to create a map) and the impacts of that decision on people (e.g., that a lower-resolution map may fail to detect areas managed by Indigenous communities using low-impact methods) but it is worthwhile to make the effort. One tactic to help make this connection would be to engage impacted stakeholders in all stages of the NCS assessment to be able to ground truth the impacts of analytical decisions.

This NCS handbook only briefly touches on the importance of climate justice. The authors of this guide acknowledge that we have much more listening, learning, and work to do in this respect, but we are committed to the principles of justice and equity in climate solutions. We also recognize that integrating climate justice into our approach will enhance climate outcomes and be key to their success.

An farmer picking peas in Minzhu Village on the edge of Laohegou Nature Reserve, Sichuan Province, China © Nick Hall/TNC

Glossary

Note: Many of the below definitions are quoted or paraphrased from the IPCC [87].

Additionality: Reductions in GHGs that occur as a direct result of an activity relative to an established baseline. If the reductions would have occurred in the absence of the activity, they are not considered additional.

Afforestation: Establishing forests in locations that have not historically supported forests, or where they have not occurred recently. Because afforestation may have negative biodiversity impacts and may not establish well, we focus on the practices of reforestation or restoration of forest cover.

Albedo: The proportion of solar radiation reflected by a surface or object, which varies by its color and other properties. Changes in albedo are important to implementation of NCS because they can counteract the mitigation benefit. For instance, restoration of forest cover, especially at high elevations or areas with seasonal snow cover, is associated with reduced albedo and a local warming effect. Expansion of tree cover needs to compensate for this effect with sufficiently high sequestration to make mitigation possible.

Baseline: The starting point against which future progress can be assessed or comparisons made[112].

Biomass: The total mass of living biological material in an area or volume. In context of NCS, usually refers to trees (including roots)[113].

Carbon markets: Trading systems through which countries or other jurisdictions may buy or sell credits in an effort to meet their jurisdictional limits on emissions[114].

Carbon offsets: Compensation for the emission of GHGs elsewhere through the purchase and claiming of carbon credits. A carbon credit represents one metric ton of CO_2e that has been sequestered or removed from the atmosphere. Credits can be bought, sold, or traded in voluntary or compliance carbon markets. For an organization or country to become carbon neutral, the total number of credits claimed must be equal to any remaining emissions on a yearly basis. For NCS projects that generate credits, the potential positive and negative impacts to biodiversity, local communities, and other ecosystem services should be considered in addition to the climate benefit[115].

Carbon pool: A system that has the capacity to store or release carbon, including above-ground biomass, below-ground biomass, litter, dead wood and soil organic carbon[10].

Carbon price: The price for avoided or released GHG emissions. May refer to the rate of a carbon tax or the price of emission permits. Often used as a proxy to represent the level of effort in mitigation policies.

Carbon sequestration: The removal of carbon from the atmosphere and its storage in natural systems. In the context of NCS, refers to CO_2 taken up by plants through photosynthesis and stored as carbon in biomass and soils[12,116].

Carbon sink: Systems that absorb and store more CO_2 than they release, reducing CO_2 concentration in the atmosphere. The main natural carbon sinks are soil, trees and other plants, and the ocean. As deforestation and global warming increase, these sinks may be weakened and reduced.

Carbon stock: The total carbon stored in an item or system, regardless of the time it took to build up[12].

Climate justice: The principle that our perspective on climate change, both the underlying drivers and the policies and projects to address it, should include human rights and environmental justice, especially with regard to vulnerable populations and marginalized communities.

Co-benefit: The added benefits to people and nature arising from acts to control climate change, other than the direct mitigation benefit.

Cost-effective NCS (100 USD per metric ton CO_2e): The level of mitigation potential of a given NCS pathway at a marginal abatement cost not greater than 100 USD per ton of CO_2e as of 2030[2]. This cost level is aligned with efforts to limit global temperature increase to less than 2°C.

Discounting: The process of converting the monetary values of costs or benefits that occur in the future into their present-value equivalents.

Extent: The applicable area (or equivalent unit) across which to measure the flux of an NCS pathway.

Flux: The transfer of GHGs between the atmosphere and natural systems, quantified as the amount of sequestration or reduced emissions per unit of extent applicable for an NCS pathway[39].

Global warming potential (GWP): "A measure of the total energy that a gas absorbs over a given period of time (usually 100 years) relative to the emissions of 1 metric ton of carbon dioxide[117]."

Leakage: An increase of GHG emissions that occurs outside the bounds of an emissions reduction activity and that results from the restrictions caused by that activity.

Low-cost NCS (10 USD per metric ton CO_2e): The level of mitigation potential of a given NCS pathway at a marginal abatement cost not greater than 10 USD per ton of CO_2e as of 2030[2].

Marginal abatement cost (MAC): The economic cost associated with preventing a unit of GHG from entering the atmosphere.

Mitigation (of climate change): Actions to reduce GHG emissions (sources) or enhance sequestration (sinks), resulting in reduced atmospheric GHG concentrations, in order to limit global warming.

Nationally Determined Contribution (NDC): A country's stated GHG emission reduction goals under the UNFCCC Paris Agreement.

Natural Climate Solutions (NCS): Conservation, improved land management, and restoration actions that increase carbon storage or avoid GHG emissions in forests, wetlands, grasslands, and agricultural lands across the globe, while also supporting people and biodiversity[2].

Nature-based Solutions (NbS): Actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits[118]. NbS include many services provided by nature (e.g., climate change mitigation, ecosystem resilience and adaptation, green infrastructure for stormwater management, and ecosystem services such as air purification).

Pathway: Specific NCS strategies e.g., *avoided coastal wetland impacts*, *nutrient management*, or *reforestation*. A pathway may include multiple types of activities.

Permanence: The length of time a climate change mitigation action persists.

REDD+: Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries[18,119]; a climate change mitigation mechanism developed by the Parties to the UNFCCC.

Social cost of carbon: The economic cost to society caused by an additional metric ton of CO_2e emissions[120].

Sustained-Flux Global Warming Potentials (SGWP): An improved measure of the radiative forcing of GHGs from standard GWP that is based upon a single pulse of GHG release to the atmosphere. SGWP is based upon continuous release of GHGs over the time and thus is more realistic[27].

Uncertainty: A measure of how accurate estimations are and the likely range in which the "true" value resides.

A bison herd grazes on the grasslands of the Medano-Zapato Ranch near Great Sand Dunes National Monument and Preserve in southern Colorado, U.S. © Ron Semrod/TNC

Additional Resources

There are numerous peer-reviewed and other publications which may be useful for your NCS analysis. We include here a subset of recommended references related to the topics covered in this guide.

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- Global Mangrove Alliance. Global Mangrove Watch.
- LandMark. Global Platform of Indigenous and Community Lands - Map.
- Karen Payne. Database of GIS Data Repositories. University of Georgia.
- Open Data of the World. ESRI.
- Food and Agriculture Organization of the United Nations. Geospatial information for sustainable food systems.

CARBON OFFSETS: LEADING VOLUNTARY CARBON STANDARDS

- Climate Action Reserve
- Gold Standard
- Verra

CLIMATE JUSTICE RESOURCES

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