UNLOCKING NATURE-BASED SOLUTIONS THROUGH CARBON MARKETS:

GLOBAL ANALYSIS OF AVAILABLE SUPPLY POTENTIAL

Technical report

David Landholm
Felipe Bravo
Ivan Palmegiani
Sara Minoli
Charlotte Streck
Szymon Mikolajczyk

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Acknowledgments

This technical report is one in a series produced by Climate Focus and the Food and Land Use Coalition (FOLU). Since September 2021, Climate Focus and FOLU have been collaborating on a research project around financing strategies for terrestrial nature-based solutions (NbS) at a country and global level. The ultimate objective of the project is to enable public and private decision-makers to prioritize and deploy activities and investments that will unlock the potential of NbS for climate mitigation, adaptation, resilience, biodiversity and beyond. Our current report series includes the publication of country-based assessments in Kenya & Colombia, as well as global analyses focused on the voluntary carbon market. For more information about the project, please see below.

Authors: David Landholm, Felipe Bravo, Ivan Palmegiani, Sara Minoli, Charlotte Streck, Szymon Mikolajczyk

Design: Elisa Perpignan, Sara Cottle, Ivan Palmegiani

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SYSTEMIQ
Talia Smith
Scarlett Benson
Mitch Groves
Abel Hemmelder
Natasha Mawdsley
Alessandro Passaro
Alex Andreoli

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Introduction

Over the next three decades, an effective and efficient transition to low-carbon economies is required to achieve the goals of the Paris Agreement and to avoid the worst impacts of climate change. To limit warming to 1.5°C or 2°C by 2100, it will be necessary to both half greenhouse gas (GHG) emissions each decade and to ramp up efforts to actively remove carbon from the atmosphere.[1]

Nature-based solutions (NbS) are actions to protect, sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature.[2] NbS are essential climate-mitigation measures, yet they receive only a small fraction of global climate finance. Although the global climate mitigation potential of terrestrial NbS has been estimated at 8-14 $GtCO_2e\ yr^{-1}$[3,4] only 3% of public climate mitigation funding is allocated to NbS, compared to 38% to renewable energies alone.[5] For the specific case of forest protection and restoration, funding only reaches, at best, 5% of the estimated total needed to align the land sector with the Paris Agreement's 1.5 °C target.[6] Well-designed and implemented NbS also have large potentials to contribute to other sustainable development goals simultaneously, including enhanced biodiversity, water quality, air quality, human health, and improved livelihoods.[7]

Carbon markets provide an opportunity to channel finance into sustainable land use. While carbon finance cannot remedy the absence of larger climate finance contributions, it can help countries to mobilize private sector resources for land use activities. Tapping into nature's mitigation potential is particularly relevant for countries that depend on NbS to meet their Nationally Determined Contributions (NDCs) under the Paris Agreement. Carbon markets play an important role in allowing companies to cost-effectively achieve their mitigation commitments, both in compliance and voluntary settings. This has driven up the demand for carbon credits over the last two years,[8,9] a trend that is expected to continue in the years ahead. Despite large uncertainties, estimates show that carbon market demand may reach 3-9.5 $GtCO_2e\ yr^{-1}$ by 2050.[10] However, it remains unknown how much cost-effective GHG emission reductions and removals NbS[11] will be able to supply to satisfy the growing carbon market demand, considering the myriad of barriers the land sector faces when it comes to operationalization under carbon finance schemes.

So far, available studies have focused on global demand for carbon credits, or on the supply-side covered a limited set of NbS measures, disregarding supply constraints

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1 This decarbonization roadmap translates to reducing global CO_2 emissions to 20 Gt $CO_2\ yr^{-1}$ by 2030, 10 Gt $CO_2\ yr^{-1}$ by 2030 and 5 Gt $CO_2\ yr^{-1}$ by 2050. Rockström, J., Gaffney, O., Rogelj, J., Meinshausen, M., Nakicenovic, N., & Schellnhuber, H. J. (2017). A roadmap for rapid decarbonization. Science, 355(6331), 1269–1271.

2 IUCN. Nature-based Solutions Definition. Retrieved from https://www.iucn.org/our-work/nature-based-solutions.

3 Roe, S., Streck, C., Beach, R., Busch, J., Chapman, M., Daioglou, V., et al. (2021). Land-based measures to mitigate climate change: Potential and feasibility by country. Global Change Biology, 27(23), 6025–6058.

4 To illustrate the scale of these numbers: the Climate Action Tracker estimated China's 2021 GHG emissions to be at 14.1 $GtCO_2e$, and the International Energy Agency estimated global transport emissions for 2019 at 8.5 $GtCO_2e$. Tracking Transport 2021. (2021). IEA. Retrieved from https://www.iea.org/reports/tracking-transport-2021.

5 Buchner, B., Baysa Naran, & de Aragão Fernandes, P. (2022). Global Landscape of Climate Finance 2021. Climate Policy Initiative (CPI). Retrieved from https://www.climatepolicyinitiative.org/publication/global-landscape-of-climate-finance-2021/.

6 NYDF Assessment Partners. (2021). Taking stock of national climate action for forests. Retrieved from https://forestdeclaration.org/resources/taking-stock-of-national-climate-action-for-forests/.

7 Smith, P., Adams, J., Beerling, D. J., Beringer, T., Calvin, K. V., Fuss, S., et al. (2019). Land-Management Options for Greenhouse Gas Removal and Their Impacts on Ecosystem Services and the Sustainable Development Goals. Annual Review of Environment and Resources, 44(1), 255–286.

8 Verra - Data and Insights VCS Quarterly Update on Q1/2020. (2020). Verra. Retrieved from https://verra.org/datainsights/april-2020/.

9 Since 2017, carbon credits' issuance grew from 49 to 300 $MtCO_2e$ in 2021, amounting to a market value of 748 billion in the first eight months of 202. More than 53% of these credits derive from NbS projects, of which 72% comes from developing countries. Donofrio, S., Maguire, P., Zwick, S., & Merry, W. (2020). Voluntary Carbon and the Post-Pandemic Recovery: A Special Climate Week NYC 2020 Installment of Ecosystem Marketplace's State of Voluntary Carbon Markets 2020 Report. Retrieved from https://wecprotects.org/wp-content/uploads/2020/11/EM-Voluntary-Carbon-and-Post-Pandemic-Recovery-2020.pdf.; Verra - Data and Insights VCS Quarterly Update on Q4/2021. (2022). Verra. Retrieved from https://verra.org/datainsights/data-and-insights-january-2022/.

10 Trove Research (2021). Future Demand, Supply and Prices for Voluntary Carbon Credits. Retrieved from https://trove-research.com/wp-content/uploads/2021/06/Trove-Research-Carbon-Credit-Demand-Supply-and-Prices-1-June-2021.pdf.

11 As per Roe et al. (2021).

other than price. However, carbon market investments face critical implementation barriers across multiple dimensions that go beyond price, including political, institutional, social, and technological factors. Further challenges to NbS mitigation supply relate to spatial restrictions – carbon projects cannot be developed everywhere as they naturally compete in practice with other land use activities.

This report addresses these important knowledge gaps and examines the role that carbon markets may play in unlocking NbS mitigation potential in the short and mid-term, both globally and at a country level. The objective of this report is to provide decision-makers – policymakers, corporates, investors, and international institutions – with information on the opportunities and gaps of accessing the carbon markets in general, and the Voluntary Carbon Market (VCM) in particular, to unlock the mitigation potential of NbS.

This report is part of a series of technical reports. The methodological approach was first piloted in Colombia, Kenya, and the US,[12,13] and is now applied analogously at a global level to better understand how much NbS mitigation potential can be supplied from carbon markets worldwide.

The report is structured into three main sections:

> **Section 1. Comparison of climate mitigation potential of NbS and actual mitigation delivered by NbS through the VCM to date.** We review relevant academic literature to assess the economic mitigation potentials for NbS activities globally, at country level, and their role in climate change mitigation pathways. We then quantify the carbon credit supply from NbS realised so far through leading VCM standards, outlining historical trends of activity types and issuance rates globally and regionally. This allows us to compare emission reductions and carbon removals already unlocked by the carbon markets to date, with the total mitigation potential available based on academic literature.
>
> **Section 2. Outlook of the NbS supply potential of carbon markets.** This section represents the heart of the report. The objectives of this section are threefold:
>
> 1. to model the projected supply NbS mitigation potential of carbon markets globally and for different regions over the 2021-2050 period;
> 2. to better understand the role that different feasibility barriers may play in relation to unlocking the carbon markets' full mitigation potential;
> 3. to identify at country level where mitigation potentials are concentrated, and for what NbS activities.

To address these objectives, the model-based analysis accounts for (i) the role of different feasibility barriers (e.g., cost, political landscape, land tenure, ease of doing business barriers) and (ii) the existing on-the-ground land uses which may further limit the uptake of carbon projects. Based on these projections, we assess the share of the total NbS mitigation potential that could realistically be unlocked by the VCM between 2021 and 2050.

Section 3. Conclusions. The report concludes by summarizing the main findings in this report.

[12] Landholm, D., Bravo, F., Palmegiani, I., Streck, C., Omuko-Jung, L., et al. (2022). Unlocking nature-based solutions through carbon markets in Kenya - Technical Report. Climate Focus. Retrieved from https://climatefocus.com/publications/unlocking-nature-based-solutions-through-carbon-markets-in-kenya/

[13] Landholm, D., Bravo, F., Streck, C., Martinez, G., Castro, J. P., Cote, L., et al. (2022). Unlocking nature-based solutions through carbon markets in Colombia - Technical Report. Climate Focus. Retrieved from https://climatefocus.com/publications/unlocking-naturebasedsolutions-through-carbon-markets-in-colombia/

01

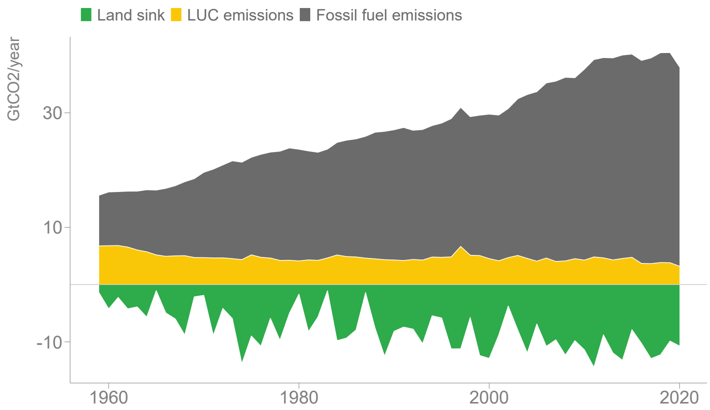
Comparison of cost-effective climate mitigation potential of NbS and actual mitigation delivered by NbS through carbon markets

1.1 Climate change and land

Land plays a vital role in regulating climate, representing both a source and a sink of GHG emissions (Figure 1).[14] Human activities in agriculture, forestry, and other land-use (AFOLU sector) are classified all together as managed land, and contribute to 23% of total net anthropogenic annual GHG emissions, including CO_2, CH_4, and N_2O. This corresponds to 12 ± 2.9 $GtCO_2e\ yr^{-1}$ of estimated annual emissions in the period 2007-2016.[15] Of these emissions, roughly half come from land-use changes, such as deforestation and wetland loss (predominantly CO_2 emissions), while the other half arise from agriculture (predominantly CH_4 and N_2O emissions). In contrast, the natural terrestrial ecosystems, classified as unmanaged land, represent a net sink of 11.2 ± 2.6 $GtCO_2\ yr^{-1}$, sequestering about 30% of total CO_2 annual emissions during the same 2007-2016 period.[16]

Just considering CO_2 fluxes, the balance between emissions from human activities on land and removals from natural lands produced a net sink of 6.0 ± 3.7 $GtCO_2\ yr^{-1}$.[17] Therefore, natural lands provide a critical carbon removal service, if left undisturbed. Over the last few decades, the land sink has been increasing, primarily because of the positive response of vegetation to increased atmospheric CO_2. Yet, the capacity of land to absorb CO_2 is being partially counterbalanced by negative temperature impacts of climate change on important terrestrial ecosystems, such as the Amazon rainforest.[18] Moreover, ongoing anthropogenic disturbance of these natural ecosystems, e.g., deforestation and forest degradation, reduces their ability to remove carbon from the atmosphere.[19] Despite regional differences and estimate uncertainties, land remains a major CO_2 sink that must be protected and is a crucial component of global mitigation strategies.[20]

Figure 1: Global emissions and land sink of CO_2 over time. Emissions are displayed by source: fossil fuels and land-use change (LUC). The sum of net land-use change emissions (yellow) and the net land carbon sink (green) produces a net sink of about 6.0 $GtCO_2\ yr^{-1}$.[21]



1.2 NbS measures and their cost-effective mitigation potentials

NbS, as defined in the Introduction, are a relatively broad set of management actions to reduce GHG emissions and/or sequester carbon in land systems (i.e., in forests, wetlands, grasslands, croplands, and pasturelands). Management measures can generally be categorized as supply and demand-side activities. Supply-side activities include (1) forests and other natural ecosystems

[14] Friedlingstein, P., Jones, M. W., O'Sullivan, M., Andrew, R. M., Bakker, D. C. E., Hauck, J., et al. (2022). Global Carbon Budget 2021. Earth System Science Data, 14(4), 1917–2005.
[15] IPCC. (2019). Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Retrieved from https://www.ipcc.ch/srccl/.
[16] IPCC. (2019).
[17] IPCC. (2019).
[18] Friedlingstein et al. (2022).
[19] Forest Declaration Assessment Partners. (2022). Overarching forest goals: Theme 1 assessment. Forest Declaration Assessment: Are we on track for 2030? Climate Focus (coordinator and editor). Accessible at www.forestdeclaration.org
[20] Grassi, G., Stehfest, E., Rogelj, J., Van Vuuren, D., Cescatti, A., House, J., et al. (2021). Critical adjustment of land mitigation pathways for assessing countries' climate progress. Nature Climate Change, 11(5), 425–434.
[21] Friedlingstein, P., Jones, M. W., O'Sullivan, M., Andrew, R. M., Bakker, D. C. E., Hauck, J., et al. (2022). Global Carbon Budget 2021. Earth System Science Data, 14(4), 1917–2005.

(to protect, manage, and restore); (2) agriculture (to reduce emissions and enhance carbon sequestration); and (3) bioenergy and other land-based energy technologies (to reduce fossil fuel emissions and sequester carbon), whereas demand-side measures include (1) food waste; (2) diets; and (3) resource use. When actions result in a net removal of carbon from the atmosphere, they are also referred to as carbon dioxide removal (CDR).

A recent study by Roe et al. (2021)[22] indicates that NbS could realistically mitigate up to 13.8 $GtCO_2e\ yr^{-1}$ between 2020 and 2050. Although their technical mitigation potential is much higher (more than double), its realization is constrained by economic factors.[23] In general, different studies agree that there is large potential (between 7 and 15 $GtCO_2e\ yr^{-1}$) to mitigate climate change through improved land stewardship or NbS measures.[24] For this report, we use the data from Roe et al. (2021) to assess the mitigation potential of various NbS activities in individual countries, aggregating this to global potentials. Specifically, we use the data from Roe et al. (2021)'s sectoral approach, which provides estimates for more than 200 countries and 20 different land-based mitigation measures.[25] Moreover, we use the data referring to the 'cost-effective' mitigation potential (available up to US$100/$tCO_2e$)[26], as this represents a more realistic target in relation to the 'technical' mitigation potential, better reflecting the public willingness to pay for climate mitigation.[27]

From the sectoral data, Roe et al. (2021) estimate 13.8 ± 3.1 $GtCO_2e\ yr^{-1}$ of global cost-effective potential is available from NbS. Of this, 50% comes from forests and other ecosystems, 35% from agriculture, and 15% from demand-side measures. Across regions, the highest cost-effective potentials are found in Asia and developing Pacific (34%), followed by Latin America and Caribbean (25%), Africa and the Middle East (18%), Developed countries (18%), and Eastern Europe and West-Central Asia (5%). About 80% of the potential is concentrated in developing and least-developed countries.

To determine the amount of mitigation potential that can theoretically be covered by carbon markets, we assessed which types of land-based mitigation activities are currently taken up by VCM investors, and which countries are supplying them. We categorized the NbS activities into five main measures that have the largest market share in the VCM today: Avoided Deforestation, Afforestation/Reforestation, Avoided Wetland Conversion and Wetland Restoration (hereafter referred to as Wetlands), Improved Forest Management, and Agriculture.[28] Based on this categorization, we excluded five mitigation measures – bioenergy, demand-side measures (diet shifts, reduced food waste, and clean cookstoves), and natural grassland fire management – leaving 15 land-based measures from the original list of 20 activities from Roe et al. (2021). We then conducted our analysis on the 50 countries that have registered VCM NbS projects.[29] The method used to assign categories to each carbon project varied

22 Roe, S., Streck, C., Beach, R., Busch, J., Chapman, M., Daioglou, V., et al. (2021). Land-based measures to mitigate climate change: Potential and feasibility by country. Global Change Biology, 27(23), 6025–6058.

23 Common types of estimated mitigation potential include "technical potential" (the biophysical potential or amount possible with current technologies), and "economic potential" (constrained by costs, generally expressed as a carbon price). Less commonly available estimates include "sustainable potential" (constrained by environmental safeguards), and "feasible potential" (constrained by environmental, socio-cultural, and/or policy barriers).

24 Other commonly cited global estimates of land-based mitigation are: the IPCC-AR5 AFOLU (2014) economic mitigation potential (<US$100/$tCO_2eq$) of 7.18 – 10.60 $GtCO_2eq\ yr^{-1}$ in 2030; the UNEP Emissions Gap (2017) potential for AFOLU of 12 (9 – 15 uncertainty range) $GtCO_2eq\ yr^{-1}$ in 2030; the cost-effective (<US$100/$tCO_2eq$) potential of 11 $GtCO_2eq\ yr^{-1}$ in 2030 estimated by Griscom et al. (2017); and the 1.5°C land-sector roadmap potential of 14 – 15 $GtCO_2eq\ yr^{-1}$ between 2030-2050 from Roe et al. (2019).

25 Roe et al. (2021) present two alternative methods, namely the sectoral approach and the Integrated Assessment Models approach.

26 US$100 is in the middle of the price range in 2030 and the low end of the range in 2050 for carbon prices in a 1.5°C pathway.

27 Roe et al. (2021).

28 The "Agriculture" activity includes mitigation potential from activities that reduce emissions and/or remove CO_2 from the atmosphere and store it in the soil and biomass. Specifically, the following activities are considered: Enteric fermentation, manure management, improved rice production, nutrient management, soil carbon sequestration on grasslands, soil carbon sequestration on croplands, agroforestry, and biochar.

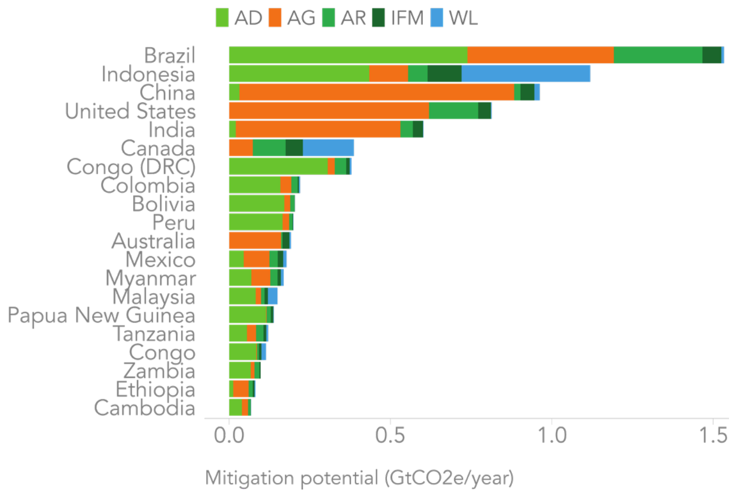
29 We consider the five leading standard organizations: Verra's Voluntary Carbon Standard (VCS), Gold Standard (GS), American Carbon Registry (ACR), Climate Action Reserve (CAR), and Plan Vivo.

depending on the standard under which each project is registered. For the Voluntary Carbon Standard (VCS) and Gold Standard (GS), the methodologies applied to each project were used to assign the categories, whereas for the American Carbon Registry (ACR), the Climate Action Reserve (CAR), and Plan Vivo – which do not list the methodologies used in each project – the project category defined by the respective standard was used. We did not consider jurisdictional REDD+ programs because at the time of our analysis no credits had been issued by either of the two available standards (ART/ TREES and VCS Jurisdictional and Nested REDD+). A detailed explanation of the method used to assign categories to each project can be found in the **Annex** (**Table 2 - Table 5**).

We find that 11.8 $GtCO_2eq\ yr^{-1}$ of cost-effective mitigation potential could be covered globally by the five categories of measures that are represented by the VCM. Out of this, 8.5 $GtCO_2eq\ yr^{-1}$ could be realized in the 50 countries that have already registered NbS projects. This is the mitigation ceiling that carbon markets (VCM and compliance markets) and other financial instruments could theoretically tackle before accounting for the different non-economic barriers existing in different countries (addressed in **Section 2**).

Of the 8.5 $GtCO_2e\ yr^{-1}$ that could be theoretically tackled by the VCM, Agriculture provides the highest global mitigation potential (45%), followed by Avoided Deforestation (30%), Afforestation/ Reforestation (10%), Wetlands (7%) and Improved Forest Management (8%). Avoided Deforestation and Wetlands also have the highest mitigation densities (total potential per unit area) by multiple orders of magnitude.[30] The top-ten countries with the largest potential are Brazil, Indonesia, China, USA, India, Canada, the Democratic Republic of Congo (DRC), Colombia, Bolivia, and Peru (Figure 2). Avoided Deforestation is the dominant mitigation opportunity in many tropical countries (Brazil, Indonesia, DRC, Colombia, among others), whereas Agriculture has the largest share in large developed and emerging economies (China, USA, India, and Australia). The potential from Afforestation/ Reforestation is more geographically distributed, with many countries presenting significant potential, particularly Brazil, USA, Canada, Indonesia, and India. Wetlands – the activity with the highest mitigation density – could also play an important role in Indonesia, Canada, and Malaysia.

Figure 2: Cost-effective (<US$100/t$CO_2$e) mitigation potential of land-based mitigation available for 15 land-based VCM measures aggregated into five main categories. Country-level mitigation potential only for the top 20 countries with already registered VCM NbS projects. The values for the other 30 countries with VCM projects are presented in the ***Annex*** *(**Figure 15**).*



Relevant high mitigation density countries include Bangladesh, Indonesia, Vietnam, Malaysia, Rwanda, South Korea, Cambodia, the Philippines, El Salvador, the Republic of the Congo, Uganda, and Papua New Guinea.[31] As expected, the highest total potential is associated with countries and regions with large land and forest areas. However, when considering mitigation density, many smaller countries, particularly those with large coastlands and wetlands, have disproportionately high levels of mitigation potentials for their size.[32]

30 Roe et al. (2021).
31 Roe et al. (2021).
32 Roe et al. (2021).

A vast majority of the measures and techniques to unlock mitigation from the five main NbS measures are relatively mature and have already been deployed in carbon market projects over the last decade.[33] The selection of which NbS measure, how, and where to implement it relies on a variety of factors however, and should consider both co-benefits and trade-offs that a project would generate. Beyond climate mitigation, land-based interventions produce a variety of interlinked impacts and implications, such as adaptation, food security, biodiversity, ecosystem services, and other environmental and societal challenges. As such, it is important to consider the quality of NbS projects, weighing the various benefits and risks related to climate and non-climate goals (see Section 4.8 of the **Annex** for more details).

1.3 Global historic supply of NbS carbon credits from the VCM (2010-2022).[34]

To assess the historic supply of carbon credits from the VCM, we compiled and analyzed data from carbon standard organizations that, together, account for over 90% of the transactions in the voluntary carbon market.[35] To be traded on the VCM, carbon credits need to be certified by independent carbon standard organizations. We derived data from five leading standard organizations: VCS, GS, ACR, CAR, and Plan Vivo (See **Section 4.1** of the **Annex** for full methodology).[36]

Since the voluntary market's inception in the early 2000s and until the third quarter (Q3) of 2022, a total of 1.4 billion carbon credits (equivalent to 1.4 $GtCO_2e$ of reduced emissions and removals have been issued. Of these, 0.48 $GtCO_2e$ (about 35%) are from NbS activities (**Figure 3**). More than half (53%) of all issued voluntary credits have already been cancelled or retired, leaving an estimated 0.63 $GtCO_2e$ in credits in circulation today, with 0.38 $GtCO_2e$ (60%) of them related to NbS activities.[37]

During the 2010-2022 Q3 period VCM has managed to unlock less than 0.5% of the annual cost-effective potential of NbS. Between 2010- 2022 Q3, the total amount of NbS related credits issued by the tracked VCM standards was 480 $MtCO_2e$, with an annual average rate of 37 $MtCO_2e\ yr^{-1}$.[38] The annual issuance in recent years (2019-2021) has increased to 98 $MtCO_2e\ yr^{-1}$, reflecting the growing demand for voluntary carbon credits across the board. Compared to the estimated cost-effective mitigation potential that can be captured by markets between 2020-2050 (8.5 $GtCO_2e\ yr^{-1}$, see Section 1.2), the VCM in the 2019 - 2021 period still delivered 1.2% of the annual potential of NbS.[39] There is therefore significant potential to scale up the carbon market's role in delivering mitigation from NbS.

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33 Agriculture VCM projects are likely the exception here. Projects targeting emissions reductions and removals in the agriculture sector have been disproportionately less frequent in the past in relation to other activities. This is explained by the comparably recent development of mitigation methodologies, by the lack of cost-effective methods for measurement, reporting and verification (MRV) of soil organic carbon (SOC) stock changes from agriculture projects, and due to challenges related to permanence.

34 Historic data includes until the third quarter (Q3) of 2022.

35 Forest Trends' Ecosystem Marketplace (2021) State of Voluntary Carbon Markets 2021: Markets in Motion. Retrieved from https://bit.ly/3AvFmx0

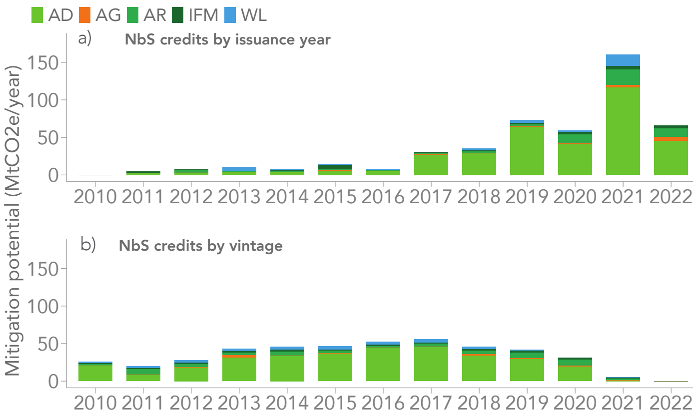
36 Project and issuance data was pulled from the following sources:
Verified Carbon Standard (2022) Project Registry. Retrieved from https://bit.ly/32OLWkJ.
Gold Standard (2022) Impact Registry. Retrieved from https://bit.ly/3cidwJX.
American Carbon Registry (2022) Public Registry. Retrieved from https://bit.ly/3iQYi19 .
Climate Action Reserve (2022) Voluntary Offset Project Registry. Retrieved from https://bit.ly/2RKxLXi.

37 Carbon credits are issued after the emission reductions or removals they represent have been monitored and third-party verified. Once issued, they are available in the market and can be transacted. After a carbon credit is transacted, it may be used by the buyer – typically a corporate – to support a claim (e.g., carbon neutrality). The carbon credit is retired from the market forever once it has been used to support a claim, so that no other entity can buy it. Carbon credits can be transacted more than once but can only be 'used' once. Carbon credits can also be canceled from the registry without being used to support any claims. In this case, the buyer makes a non-offset use of the credit to promote the achievement of net-positive environmental benefits.

38 The earliest carbon credit issuances from NBS projects dates back to 2010 by projects VCS142 - "Reforestation of degraded grasslands in Uchindile & Mapanda, Tanzania" in Tanzania, and ACR114 – "GreenTrees ACRE (Advanced Carbon Restored Ecosystem)" in the USA.

39 This estimate is using issuances from the 2019-2021 period. In reality, a lot of credits had been waiting to be issued for demand to appear, so the VCM is likely unlocking <1% if it were possible to account for this.

Figure 3: Annual distribution of credits from the voluntary carbon market between 2010-2022. One VCM credit represents one tCO_2e sequestered or not emitted. Credits are displayed by NbS activity (colors), issuance year (top panel), and vintage (year when the emission reduction has occurred, bottom panel).[40]*



**2022 data presents issuances until Q3.*

Driven by increasing demand, the issuances of NbS credits have been increasing over the past decade, peaking in 2021 with a volume more than double than that of the previous year (Figure 3a). The growth has slowed down in 2022, when issuances have been tangibly lower by Q3 (189 $MtCO_2e$) than in Q3 of 2021 (272 $MtCO_2e$). Credit vintages, which reflect the year when emission reductions occurred rather than when it was issued, present highest values (40-50 $MtCO_2e\ yr^{-1}$) between 2013-2017 (Figure 3b). The relatively low values for 2018 – 2022 vintages are explained by the time it takes for project developers to monitor and verify the emission reductions, and for the registries to issue the carbon credits once they have been verified. This can therefore be seen as an incomplete data picture, rather than a reduction in the mitigation being unlocked during this period.

Since 2010, the majority (73%) of total NbS issued credits were generated by Avoided Deforestation, delivering in total 348 $MtCO_2e$ of reduced emissions (Figure 3a). The proportion of vintages from the five NbS activities have remained relatively stable over the last decade. In the last nearly four years (2019 to 2022 Q3), Avoided Deforestation delivered 268 $MtCO_2e\ yr^{-1}$, accounting for 75% of the credits issued. In the same period, the share of Afforestation/Reforestation credits issued was 14%, while Wetlands and Improved Forest Management made up 6% and 4% of the total credits, respectively. Lastly, credits from Agriculture represented only 2% of the total issuances. The total increase in issued credits since 2015 has been observed across all five activities, albeit at different rates.

1.4 Historic country-level supply of NbS carbon credits from the (2010-2022)[41]

For the period 2010-2022 Q3, 50 countries have supplied NbS carbon credits through voluntary carbon market activities. When accounting for all VCM activities (i.e., non-NbS and NbS activities), the leading offset suppliers have been India, China, USA, and Brazil. For NbS credits only, the leading suppliers during this period were Indonesia, Peru, Brazil, Cambodia, and Colombia, with 75, 65, 65, 39, and 32 $MtCO_2e$, respectively. These top five countries represent 58% of the supplied credits in the last decade. DRC, Kenya, USA, Zimbabwe, China, and Uruguay also supplied a moderate amount (more than 10 $MtCO_2e$) of NbS carbon credits. The remaining 39 countries have, so far, supplied less than 10 $MtCO_2e$ each, with the majority remaining below 5 $MtCO_2e$.

In recent years (2019-2022 Q3), China has entered the top 5 NbS-supplier countries, which otherwise saw only small changes in their ranking in relation to the 2010-2022 period. Particularly, Peru became the leading country with about 54 $MtCO_2e$, followed by Brazil, Indonesia, Cambodia, China, and Colombia, with 53, 51, 39, 20, and 20 $MtCO_2e$, respectively, over the 4-year time period (**Figure 4**). Zimbabwe, Kenya DRC, and the U.S. increased offsets to over 15 $MtCO_2e$. About half of the countries show increasing supply trends

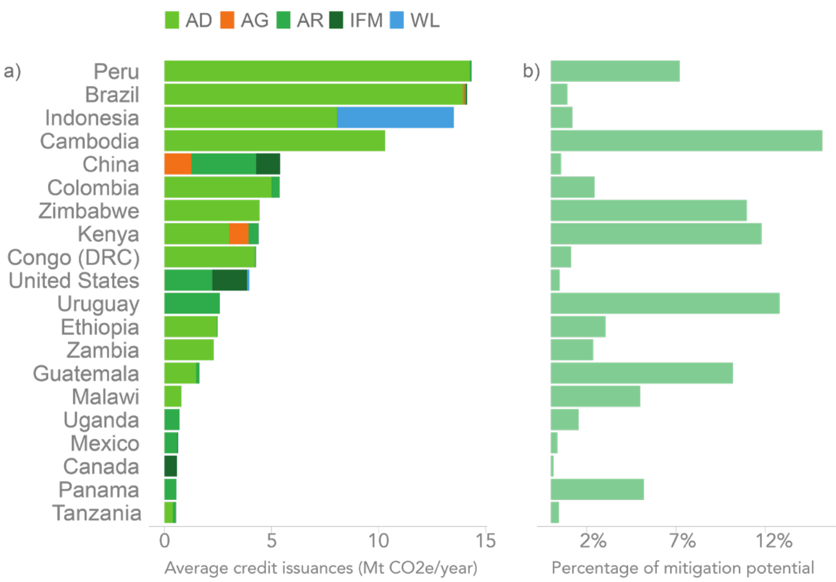
40 Climate Focus analysis based on public VCM data from Verra VCS, Gold Standard, American Carbon Registry, Climate Action Reserve, and Plan Vivo.

41 Historic data includes until the third quarter (Q3) of 2022.

in recent years (2019-2021)[42], with strong growth rates found for Cambodia, Uruguay, Kenya, Guatemala, Zimbabwe, Peru, Panama, Vanuatu, Ethiopia, and Malawi (**Figure 5**).

During the 2019 - 2022 Q3 period, the two NbS activities that have issued the largest share of credits per country have been Afforestation/Reforestation and Avoided Deforestation. Particularly, Afforestation/ Reforestation activities were the most prominent across 43% of the countries, including China, USA and Uruguay, while Avoided Deforestation activities were most relevant in 40% of the countries, including Peru, Brazil, India, and Indonesia. Improved Forest Management was most important in 13% of the countries, including Canada, Mongolia, and Congo. Wetlands activities presented the largest issuances in only two countries (4%), including Senegal and Myanmar. Finally, Agriculture activities did not lead issuances in any country, but were fairly well represented in China and Kenya.

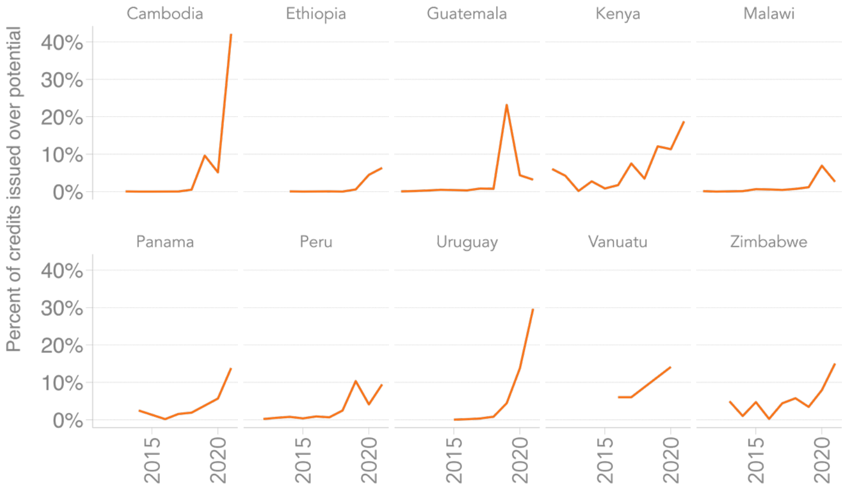
Figure 4: Historic country-level credit issuance by NbS activity (2019-2022 Q3). a) Annual average credit issuance in 2019-2022 Q3 for each country. b) Annual average credits issued in 2019-2022 Q3 as a percentage of its annual cost-effective mitigation potential in 2020-2050.[43]



Overall, the volumes of carbon credits issued through NbS activities is still relatively small compared to what could be potentially supplied. Many countries with a high NbS mitigation potential show very limited uptake of NbS activities under the VCM, while others with a much more modest potential rank among the highest of all countries active in the market. Over the period 2019-2022 Q3, Cambodia, Uruguay, Kenya, Zimbabwe, and Guatemala have the highest (larger than 10%) issuances of NbS on the carbon market, relative to their annual, average cost-effective mitigation potential in 2020-2050 (**Figure 4**).[44] In contrast, the countries with the lowest (less than 1%) relative supply of NbS during the 2019-2022 Q3 period compared to their cost-effective mitigation potential are India, Bolivia, DRC, Canada, China, USA, alongside many smaller countries. These results indicate that generally, high NbS mitigation potentials at country level have not translated yet into high NbS uptake through the VCM, regardless of the region. In contrast to the average issuances over the 2019-2022 Q3 period presented in **Figure 4**, **Figure 5** presents the annual issuances since 2010 as a percentage of their cost-effective mitigation potential.

[42] For 2022 up to Q3, issuances have slowed down in relation to 2021.
[43] Climate Focus analysis based on public VCM data from Verra VCS, Gold Standard, American Carbon Registry, Climate Action Reserve, and Plan Vivo; and data from Roe et al. (2021).
[44] Roe et al., (2021).

Figure 5: Trajectory of NbS credits issued since 2010 as a percent of each country's mitigation potential.[45] The figure displays the countries presenting the highest percent of issuances change.[46] To illustrate, in the last year of data Cambodia issued credits that represented over 40% of Cambodia's yearly cost-effective mitigation potential.



45 Roe et al. 2021

46 Climate Focus analysis based on public VCM data from Verra VCS, Gold Standard, American Carbon Registry, Climate Action Reserve, and Plan Vivo; and data from Roe et al. (2021).

Outlook of the NbS supply potential of carbon markets

The objective of this section is threefold:

1. to estimate the future NbS mitigation that can be further unlocked globally through the voluntary carbon market until 2050;

2. to better understand the role different feasibility barriers may play in relation to unlocking the carbon markets' full mitigation potential; and

3. to identify at a regional and country level where this mitigation potential is concentrated for different activities.

The modeling exercise presented in this section accounts, firstly, for the role of different feasibility barriers (e.g., cost, political, land tenure, business climate), and, secondly, for the existing on-the-ground land uses which may further limit the uptake of carbon projects. Based on these potential projections, we assess the share of the total cost-effective mitigation potential (**Section 1**) that could be delivered through the VCM in the future.

2.1 Overview of methodological approach

We have developed a country-level (bottom-up) model that explores how much GHG mitigation can be unlocked by NbS activities through carbon markets over time, accounting for both economic and other country-specific constraints (Figure 6). The model accounts for:

1. The mitigation potentials of the five NbS activities per country[47] (Avoided Deforestation, Afforestation/Reforestation, Agriculture[48], Improved Forest Management, and Wetlands);

2. Three carbon market price scenarios until 2050 (**Figure 11**)[49];

3. Key feasibility barriers to the implementation of these NbS measures, related to the ease of doing business, land tenure, and political factors; and

4. Further restrictions to NbS implementation posed on-the-ground by previously existing land uses (hereafter referred to as "locked-in land uses"). Specifically, we consider economic land concessions[50], extractive industries such as mining, oil and gas concessions[51], and protected areas.[52] In some geographies, carbon projects developed in protected areas may not comply with additionality criteria: due to the uncertainty surrounding protected areas, here we consider three different scenarios (see **Sections 4.4** and **4.5**).

A visual overview of the methodology can be found in Figure 6, while a detailed description of the model and approach can be found in the **Annex** (**Sections 4.2 - 4.5**).

[47] Roe, S., Streck, C., Beach, R., Busch, J., Chapman, M., Daioglou, V., et al. (2021). Land-based measures to mitigate climate change: Potential and feasibility by country. Global Change Biology, 27(23), 6025–6058.

[48] The "Agriculture" activity includes mitigation potential from activities that reduce emissions and/or remove CO_2 from the atmosphere and store it in the soil and biomass. Specifically, the following activities are considered: Enteric fermentation, manure management, improved rice production, nutrient management, soil carbon sequestration on grasslands, soil carbon sequestration on croplands, agroforestry, and biochar.

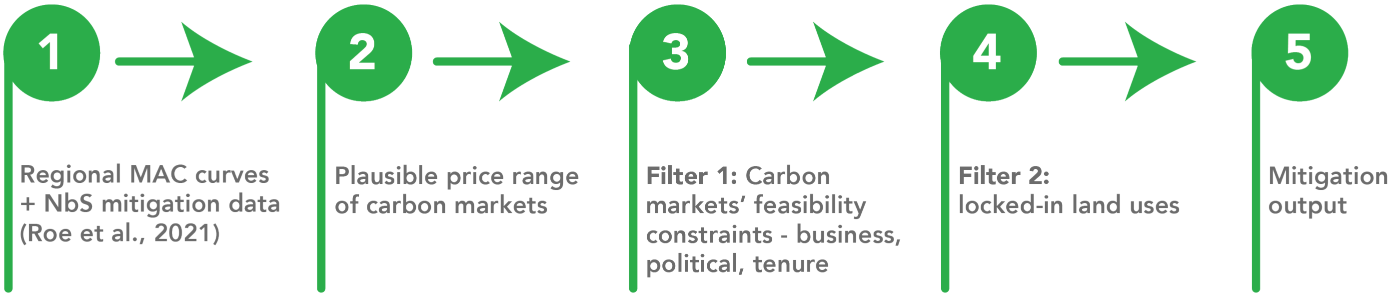
[49] Given the long time-frame considered (until 2050), a simple and transparent scenario-based approach is preferred over modeling specific price forecasts, which is particularly complex in the very uncertain carbon market environment.

[50] Land Matrix: Public database on land deals (n.d.). Retrieved from https://landmatrix.org/.

[51] Mines footprints provided in Maus et al. (2021) were used to identify the location of active mining projects. Further, we calculate the ratio between mine footprints and the respective mining concessions as provided on Global Forest Watch to estimate the size of concessions where the mine footprint is known but not the respective concession area. Maus, V., Giljum, S., Gutschlhofer, J., da Silva, D. M., Probst, M., Gass, S. L. B., et al. (2020). Global-scale mining polygons (Version 1). PANGAEA. Retrieved from https://doi.pangaea.de/10.1594/PANGAEA.910894. Global Forest Watch. (n.d.). "Mining concessions." Retrieved from www.globalforestwatch.org.

[52] IUCN and UNEP-WCMC. (2022). The World Database on Protected Areas (WDPA). Retrieved from www.protectedplanet.net.

Figure 6: Schematic overview of the methodology applied to obtain the NbS mitigation potential that can be unlocked by carbon markets.



2.2 Results and discussion

Global NbS mitigation potential of carbon markets

Under assumed constraints, carbon markets could unlock up to 14%, 32%, and 35% of the global cumulative mitigation potential of NbS activities by 2023, 2030, and 2050, respectively. This corresponds to a cumulative 89.8 $GtCO_2e$ (range: 65.2-113.0) out of Roe et al (2021)'s 255.1 $GtCO_2e$ potentially achievable in 2050 (8.5 $GtCO_2e\ yr^{-1}$) (**Section 1.2**). On a yearly basis, the carbon markets could unlock up to 1.2 $GtCO_2e\ yr^{-1}$ (range: 0.9-1.5), 2.7 $GtCO_2e\ yr^{-1}$ (range: 1.9-3.6), and 4.2 $GtCO_2e\ yr^{-1}$ (range: 3.2-5.1) by 2023, 2030 and 2050, respectively. These results account for the different constraints considered, namely price, implementation feasibility, and spatial location, and explain why the modeled available mitigation potential for carbon markets is substantially lower than Roe et al. (2021)'s cost-effective mitigation potential.

Even to reach this lower available mitigation, our results signal that a steep increase is needed: to reach the available mitigation in 2030 of 2.7 $GtCO_2e\ yr^{-1}$, carbon markets would need to grow by a factor of 17 in relation to 2021 levels.[53] This represents a compound annual growth rate of 37% per year. The rapid growth required starts to moderate during the second half of the decade (**Figure 7**). These broad dynamics are determined mainly by the regional Marginal Abatement Cost Curves (MACC), which reflect decreasing amounts of mitigation unlocked as prices increase beyond a certain threshold (an example is shown for the Agriculture activity in **Figure 10**, **Annex**). Although a 17-fold increase by 2030 appears ambitious, the recently launched Africa Carbon Markets Initiative plans for a 19-fold increase in African credit retirements to 300 $MtCO_2e\ yr^{-1}$ by 2030.[54] Leading standard organizations are also gearing up to manage increased level of activity, with organizations like Verra having recently reported internal restructuring to increase capacity in order to deal with an ongoing and expected surge of new projects.[55]

In terms of activities, Agriculture dominates the carbon market potential globally, with 43% of the total mitigation potential in 2030 (1.15 $GtCO_2e\ yr^{-1}$), followed by Avoided Deforestation (32%, 0.86 $GtCO_2e\ yr^{-1}$), Afforestation/Reforestation (11%, 0.28 $GtCO_2e\ yr^{-1}$), Improved Forest Management (7%, 0.19 $GtCO_2e\ yr^{-1}$), and Wetlands (7%, 0.19 $GtCO_2e\ yr^{-1}$). Given the slow development of this activity today, **Section 2.2.4** provides a detailed discussion of the main challenges to overcome to unlock this potential.

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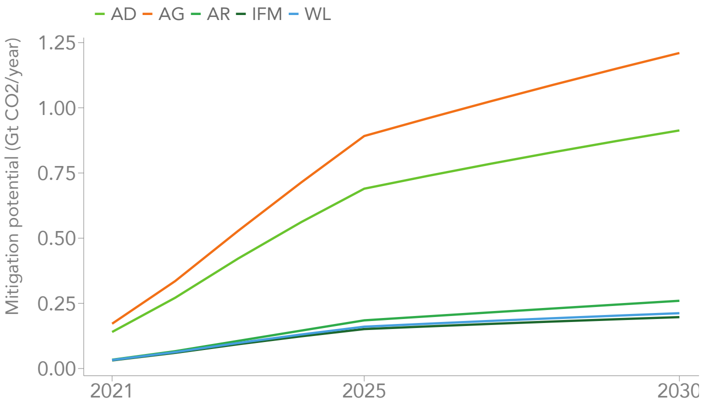
[53] Global NbS issuances across the five activities amounted to 160.3 $MtCO_2e$ in 2021 or 6% of the available mitigation potential in 2030.

[54] ACMI (2022): Africa Carbon Markets Initiative (ACMI): Roadmap Report. Retrieved from https://www.seforall.org/system/files/2022-11/ACMI_Roadmap_Report_Nov_2022.pdf.

[55] Verra. (2022). Pardon Our Dust: How Verra Is Meeting The Demands Of Tomorrow's Carbon Market. Retrieved from: https://verra.org/pardon-our-dust-how-verra-is-meeting-the-demands-of-tomorrows-carbon-market/

Figure 7: Mean estimates of mitigation potential available for five NbS activities in the carbon markets. These estimates should be interpreted as upper limit estimates. ***Figure 14*** *(**Annex**) presents the uncertainty associated to the methodological approach, while Figure 16 (**Annex**) presents the estimates in relation to the cost-effective mitigation potential of Roe et al. (2021).*



Regional and national NbS mitigation potential of carbon markets

Regionally, our model estimates the available carbon market potential for Agriculture to be largest in Asia (0.59 $GtCO_2e\ yr^{-1}$, range: 0.46-0.75) and high in OECD+EU countries (0.34 $GtCO_2e\ yr^{-1}$, 0.23-0.46) and Latin America (0.22 $GtCO_2e\ yr^{-1}$, 0.16-0.30) (**Table 1**). The top 5 countries with highest Agriculture potential from carbon markets are the U.S. (330.0 $MtCO_2e\ yr^{-1}$, 223.5-444.9), China (302 $MtCO_2e\ yr^{-1}$, 234.7-381.0), India (212.0 $MtCO_2e\ yr^{-1}$, 165.0-265.5), Brazil (157 $MtCO_2e\ yr^{-1}$, 110.8-210.4), and Indonesia (46.4 $MtCO_2e\ yr^{-1}$, 35.3-59.1).

Carbon markets' regional mitigation potential for Avoided Deforestation is largest in Latin America (0.54 $GtCO_2e\ yr^{-1}$, 0.36-0.73) and Asia (0.30 $GtCO_2e\ yr^{-1}$, 0.22-0.4). The top 5 countries with highest Avoided Deforestation potential from carbon markets are Brazil (327.00 $MtCO_2e\ yr^{-1}$, 214.53-439.77), Indonesia (188.00 $MtCO_2e\ yr^{-1}$, 135.21-244.62), Colombia (83.90 $MtCO_2e\ yr^{-1}$, 56.86-112.83), Peru (74.70 $MtCO_2e$ yr1, 53.11.29-97.73), and Malaysia (43.9 $MtCO_2e\ yr^{-1}$, 27.19-59.74).

The mitigation potential from the remaining activities is comparatively lower: Afforestation/Reforestation[56] present the largest potential in Latin America (0.13 $GtCO_2e\ yr^{-1}$, 0.10-0.17), while Wetlands[57] and Improved Forest Management[58] is most promising in Asia (0.19 $GtCO_2e\ yr^{-1}$, 0.14-0.24; 0.09 $GtCO_2e\ yr^{-1}$, 0.07-0.12). **Table 1** presents the breakdown of mitigation potential per activity by region, while a full list of the VCM countries considered and their mitigation potential across activities in presented in the **Annex** (**Table 5**).

Table 1: Available Nature-based Solutions mitigation potential by 2030 for carbon markets

NbS	Region	Mitigation potential 2030 ($GtCO_2e$/year)
AG	AS	0.59 (0.46-0.75)
	OECD-EU	0.34 (0.23-0.46)
	LAM	0.22 (0.16-0.3)
	AF	0.05 (0.03-0.07)
AD	LAM	0.54 (0.36-0.73)
	AS	0.31 (0.22-0.4)
	AF	0.07 (0.04-0.1)
	OECD-EU	0.00 (0-0)
AR	LAM	0.13 (0.1-0.17)
	OECD_EU	0.06 (0.04-0.09)
	AS	0.05 (0.04-0.07)
	AF	0.01 (0.01-0.02)
IFM	AS	0.09 (0.07-0.12)
	OECD-EU	0.05 (0.03-0.06)
	LAM	0.04 (0.03-0.06)
	AF	0.01 (0.01-0.02)

56 The top 5 countries with highest Afforestation/Reforestation potential are Brazil (103.0 Mt $CO_2e\ yr^{-1}$, 75.6-133.4), United States of America (61.5 Mt $CO_2e\ yr^{-1}$, 40.66-87.21), Indonesia (19.7 Mt $CO_2e\ yr^{-1}$, 14.37-25.94), India (13.6 Mt $CO_2e\ yr^{-1}$, 10.31-17.57), and Mexico (9.6 Mt $CO_2e\ yr^{-1}$, 7.0-12.71).

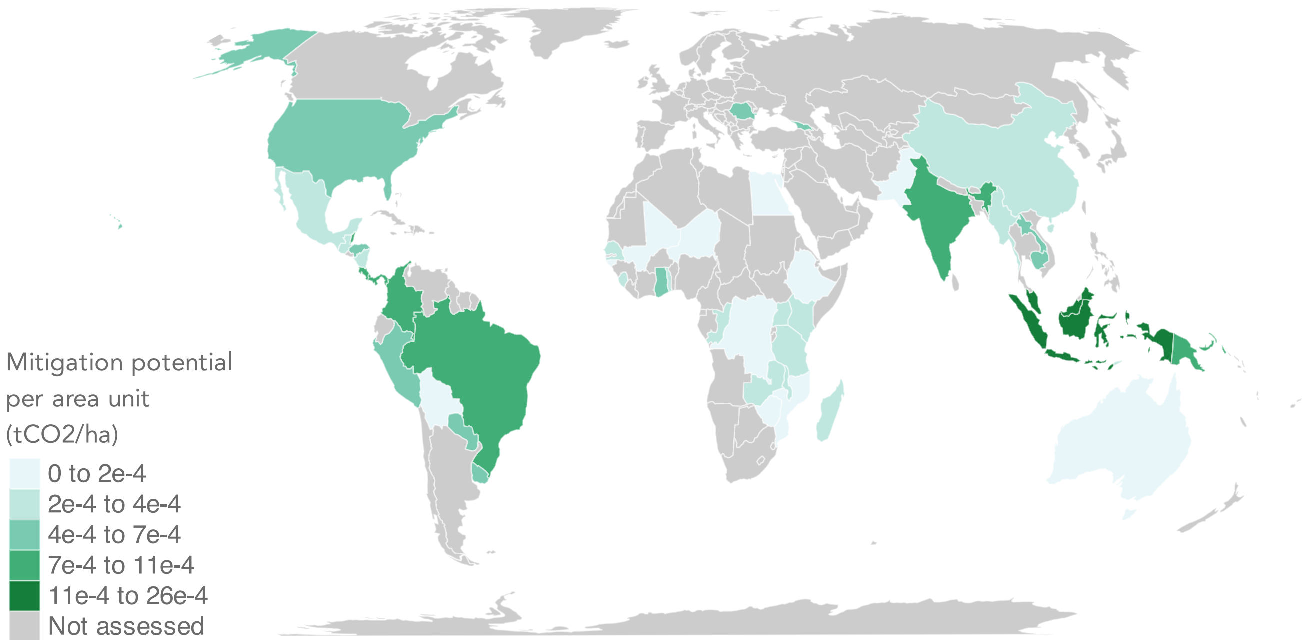
57 The top 5 countries with highest WL potential from carbon markets are Indonesia (168 Mt $CO_2e\ yr^{-1}$, 127.01-212.81), Malaysia (15.1 Mt $CO_2e\ yr^{-1}$, 10.8-19.39), China (6.45 Mt $CO_2e\ yr^{-1}$, 5.14-7.96), Mexico (4.92 Mt $CO_2e\ yr^{-1}$, 3.67-6.44), and Brazil (3.85 Mt $CO_2e\ yr^{-1}$, 2.81-4.92).

58 The top 5 countries with highest Improved Forest Management potential from carbon markets are Indonesia (47.3 Mt $CO_2e\ yr^{-1}$, 34.11-61.47), Brazil (25.3 Mt $CO_2e\ yr^{-1}$, 16.6-34.04), China (17.6 Mt $CO_2e\ yr^{-1}$, 14.04-21.73), India (15.3 Mt $CO_2e\ yr^{-1}$, 9.51-21.36), and Australia (15.3 Mt $CO_2e\ yr^{-1}$, 9.51-21.36).

NbS	Region	Mitigation potential 2030 ($GtCO_2e$/year)
WL	AS	0.19 (0.14-0.24)
	LAM	0.01 (0.01-0.02)
	AF	0.00 (0-0.01)
	OECD-EU	0.00 (0-0.01)

Accounting for country size, the five countries with the largest mitigation potential across all NbS activities are Indonesia, Malaysia, Costa Rica, Colombia, and Belize (Figure 8). While the estimates of absolute mitigation potential presented above may serve as useful indicators of the potential market volume at a country level, these values are correlated to countries' size, with larger countries like U.S., Brazil, and China presenting larger mitigation potentials than smaller ones.[59] **Figure 8** presents a complementary metric that accounts for country size and allows to gauge opportunity potential across countries.

Figure 8: Estimates of the cumulative mitigation potential unlocked by carbon markets in 2030 divided by the area of the country. Countries colored in darker tones are estimated to have higher mitigation potential per area unit than countries colored in lighter tones.[60]



Feasibility barriers and locked in land uses

Implementation feasibility barriers reduced the available NbS mitigation potential accessible through carbon markets by 35% globally. To generate the results presented above, a large amount of mitigation potential was discounted from the model to account for a myriad of barriers, namely political factors, business climate, and land tenure (see methodology in the **Annex**, **Section 4.3**). Considering regional areas, feasibility barriers were most important for Africa (71% of mitigation discounted), followed by Asia, and Latin America, with 36% and 32% reductions, respectively.

Similarly, albeit to a lesser extent, locked-in land uses reduce the amount of NbS mitigation available globally. After considering oil and gas concessions, mining concessions, economic land concessions, and protected areas, mitigation available to carbon markets was reduced by a further 11%. Protected areas

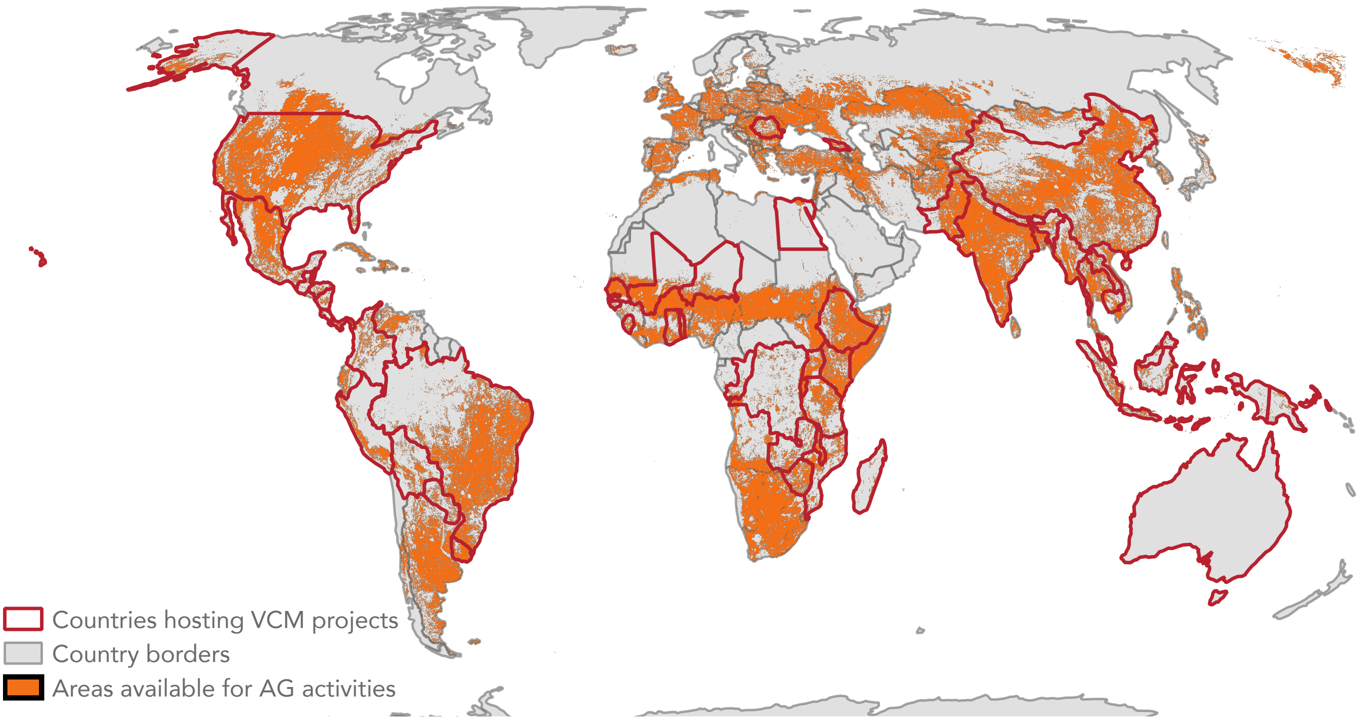
[59] Ideally, a more appropriate metric for comparison could be derived by dividing the mitigation potential by the area of the activity, instead of the country size. However, we don't have this information for some activities, namely for Improved Forest Management and Wetlands. Readers interested in mitigation density values per NbS and country may find them in Roe et al. (2021).

[60] It is important to note that these are not mitigation density values, since the mitigation potentials are divided by the area of the country, not by the areas of activity. We do not have spatially explicit information on the area of opportunity for some activities (e.g., Improved Forest Management). Still, it provides a proxy to gauge where opportunities are largest for carbon projects.

are considered a restriction because they may limit the establishment of carbon projects due to additionality criteria (See **Sections 4.4** and **4.5** of the **Annex** for details on why protected areas are considered in this approach and the different scenarios included). Considering individual NbS activities, the mitigation potential of Agriculture, Avoided Deforestation, and Afforestation/Reforestation decreased by 11%, 11%, and 7%, respectively, due to locked-in land uses. Avoided Deforestation stood out as disproportionally affected in Africa, presenting a decrease of the available mitigation potential equal to 17%.

Current challenges to meeting carbon markets' potential

Figure 9: Global area of opportunity for agriculture.[61] The dataset has been modified to exclude locked in land uses, namely mining, oil and gas concessions, economic concessions, and international protected areas. Countries with existing VCM NbS issuances are outlined in red (countries with issuances of any NbS project type).



Although Agriculture represents the activity with the largest potential globally and offers opportunities in most geographies (Figure 9), in practice numerous activity-specific barriers hinder the proliferation of this project type.[62] First, a major constraint is related to the need for cost-effective methods for measurement, reporting, and verification (MRV) of soil organic carbon (SOC) stock changes from agriculture projects,[63] and to the development of models which link specific agricultural interventions to SOC changes. Second, issues related to permanence and additionality remain a source of concern limiting the development of agriculture carbon projects. Although questions of permanence affect most removal activity categories, it is particularly challenging in the context of agriculture, where practices can change quickly on an annual basis. Similarly, there are specific additionality concerns for this project type, since not all carbon standards

[61] FAO (2022): Global Soil Sequestration Potential (GSOCseq) Map. Retrieved from https://www.fao.org/soils-portal/data-hub/soil-maps-and-databases/global-soil-organic-carbon-sequestration-potential-map-gsocseq/en/

[62] Wongpiyabovorn, O., Plastina, A., & Crespi, J. M. (2022). Challenges to voluntary Ag carbon markets. Applied Economic Perspectives and Policy. Retrieved from https://onlinelibrary.wiley.com/doi/full/10.1002/aepp.13254.

[63] Villegas, D., Bastidas, M., Matiz-Rubio, Ruden, A., Rao, Hyman, et. al. (2021). Soil carbon stocks in tropical pasture systems in Colombia's Orinoquía region: supporting readiness for climate finance - CCAFS Info Note. Retrieved from https://cgspace.cgiar.org/bitstream/handle/10568/116231/2021%20Info%20Note%20SOC_WB_HSJ_Final_Nov_22.pdf.

require farmers to change practices to comply with additionality requirements. Some merely require that practices in the field be different from common practices in the area, even if the same practices have been implemented for many years.[64] This potential quality concern may limit demand for Agriculture credits and hence affect actual supply. Finally, in addition to these technical barriers, there are numerous cultural challenges that need to be overcome for farmers to change their practices[65] – they will likely only do so if there is a clear business case and such activities are strongly promoted. The three activity-specific barriers presented here are not quantitatively considered in our model.[66]

The development of carbon accounting methodologies for Agriculture activities has lagged when compared to the established methodologies for Avoided Deforestation, Afforestation/Reforestation and Improved Forest Management.[67] The lack of available methodologies in the past applicable to agriculture projects has been another reason behind the relatively low number of projects in this sector to date. Until recently, project opportunities in the regenerative agricultural area were mainly centered around grassland management and rotational grazing, which concentrate around 95% of the carbon credits issuances in the agriculture sector to date.[68] However, this trend might change in the future with the refinement of existing methodologies and the development of new ones. To date, although only three cropland projects have been registered under Verra's "Adoption of Sustainable Agricultural Land Management" methodology,[69] there is an increasing number of projects under development under different standards.[70]

Despite existing challenges, the alignment of three different factors offers a positive mid-term outlook for the development of Agriculture carbon projects. Firstly, over the next years many technical barriers are expected to be overcome, as maturing technological advancements provide information on how soil responds to a myriad of practices in different regions, and therefore models may reduce uncertainty and bring down the costs associated with MRV.[71] Secondly, Agriculture presents a diversified set of project designs and activities that can both reduce emissions and sequester carbon,[72] and agriculture projects are of interest to a wide range of stakeholders, including NGOs that are ready to work with local communities. Finally, there is a lot of political momentum targeting emissions reductions and removals in the agricultural sector. To illustrate, as part of Glasgow's COP26, at least five declarations were made that mention widely emission reductions and removals from the

64 Wongpiyabovorn, O. et al. (2022).

65 Anastasiadis, S. and Chukova, S. (2019), An inertia model for the adoption of new farming practices. Intl. Trans. in Op. Res., 26: 667-685. Retrieved from https://doi.org/10.1111/itor.12336.

66 The model accounts for three main barriers that are relevant across all five activities (political factors, land tenure, and ease of doing business). There are, however, additional activity-specific barriers which are not captured by the model. For instance, it is difficult to model when a technological breakthrough may take place that allows for reduced MRV costs and for the scaling of this activity, or how market participants' perception and standards' rules concerning additionality may evolve over time and affect the demand for these credits. Section 4.6 presents a detailed discussion of the limitations of our study.

67 Taskforce on Scaling Voluntary Carbon Markets (2021). Final Report. Retrieved from https://www.iif.com/tsvcm.

68 The remaining 5% comes from projects applying the methodologies "Methodology for Improved Agricultural Land Management" and "Soil Enrichment Protocol" from Verra and CAR. These projects are described in the footnotes below.

69 Verified Carbon Standard (n.d.) VM0017 Adoption of Sustainable Agricultural Land Management, v1.0, Retrieved from https://verra.org/methodology/vm0017-adoption-of-sustainable-agricultural-land-management-v1-0/. The projects using this methodology are (1) VCS1704 - "Agricultural Land Management project in Beed District, India implemented by Godrej Properties Ltd." in India, Available at https://registry.verra.org/app/projectDetail/VCS/1704; (2) VCS1225 – "Kenya Agricultural Carbon Project" in Kenya, available at https://registry.verra.org/app/projectDetail/VCS/1225; and (3) VCS1532 – "COMACO Landscape Management Project" in Zambia, available at https://registry.verra.org/app/projectDetail/VCS/1532

70 The VCS project pipeline shows 19 projects in the registration process as of Q3 2022, with 16 of them located in India, two in Kenya, and one in Mozambique. Other recent and relevant developments in this area include the publication of the methodologies "Methodology for Improved Agricultural Land Management" and "Soil Enrichment Protocol" in 2020, under Verra's VCS and CAR, respectively. Two projects have been recently registered using CAR's methodology and 33 projects are currently in Verra's registration process. Of these, 18 are located in China, five in South Africa, and two in the US. Other numerous initiatives are ongoing and may contribute further to the expansion of agriculture carbon projects.

71 European Commission, Directorate-General for Climate Action, Radley, G., & Keenleyside, C. (2021). Technical guidance handbook: setting up and implementing result based carbon farming mechanisms in the EU. Retrieved October 11, 2022, from https://data.europa.eu/doi/10.2834/12087.

72 Roe, S. et al. (2021). Land-based measures to mitigate climate change: Potential and feasibility by country. Global Change Biology, 27, 6025– 6058.

agricultural sector.[73] This interest is translating into both concrete policy measures and roadmaps, such as the EU's incipient Carbon Farming initiative.[74] Recent developments at COP27 will broadly affect all NbS activities too: as examples, the U.S. presented its strategic plans for advancing NbS[75] and the Africa Carbon Markets Initiative[76] was recently launched.

Avoided Deforestation also faces a set of activity-specific challenges despite dominating the space with three quarters of NbS issued credits over the past four years. At the project level, a wide range of methodologies exist that have allowed – in some cases – for the establishment of inflated deforestation baselines and the associated overestimation of mitigation offered by projects.[77] While standards are in the process of addressing these challenges, this has raised integrity concerns around Avoided Deforestation projects. In spite of this, recent research has shown that Avoided Deforestation projects have, collectively, proved to be an effective mitigation strategy – projects reduced deforestation by 47% in the global locations where they operate in relation to matched counterfactuals.[78] Another challenge consists in the alignment of government programs at the jurisdictional level and Avoided Deforestation projects. It is important to ensure that subnational and project level accounting are aligned, i.e., that projects are "nested" into jurisdictional programs.[79] However, the variety and complexity of existing project methodologies makes the nesting of project level mitigation with national accounting methods challenging.[80] Standards continue to tackle both issues by increasing the quality of their methodologies; for instance, Verra's consolidated REDD methodology uses the same allocation approach as the VCS Jurisdictional and Nested REDD+ framework, making it difficult for projects to exaggerate their achievements via inflated baselines while facilitating the nesting of projects in jurisdictional accounting.[81] The emergence of jurisdictional programs has also seen a decline in new Avoided Deforestation projects since 2014.[82] However, so far jurisdictional programs have yet to deliver significant quantities of carbon credits to the market.

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[73] The Glasgow Leaders' Declaration on Forests and Land Use, the Glasgow Food and Climate Declaration, the Agriculture Innovation Mission for Climate pledge, the Policy Action Agenda for a Just Transition to Sustainable Food and Agriculture, and, finally, the methane pledge, where over 100 countries agreed to reduce methane emissions to 30% of 2020 levels by 2030, which has implications for the livestock sector.

[74] European Commission et al. (2021).

[75] At the time of this writing, the U.S. announced on the sidelines of COP27 strategic plans for advancing NbS, referencing support for a "NbS solutions roadmap" with over $25 billion from new and recent interagency commitments. The roadmap outlines five strategic areas of focus: updating policies, unlocking funding, leading with federal facilities and assets, training the NbS workforce, and prioritizing research, innovation, knowledge, and adaptive learning. The roadmap is designed to leverage investments made under the US infrastructure bill and the Inflation Reduction Act (IRA).

[76] The Africa Carbon Markets Initiative (ACMI) aims to dramatically expand Africa's participation in voluntary carbon markets: to grow credit retirements by 19-fold to 300 Mt CO2e yr^{-1} by 2030. ACMI (2022): Africa Carbon Markets Initiative (ACMI): Roadmap Report. Retrieved November 15, 2022, from https://www.seforall.org/system/files/2022-11/ACMI_Roadmap_Report_Nov_2022.pdf

[77] Stibniati S Atmadja et al. (2022): How do REDD+ projects contribute to the goals of the Paris Agreement? Environ. Res. Lett. DOI 10.1088/1748-9326/ac5669

[78] Guizar-Coutiño A, Jones JPG, Balmford A, Carmenta R, Coomes DA. A global evaluation of the effectiveness of voluntary REDD+ projects at reducing deforestation and degradation in the moist tropics. Conserv Biol. 2022 Dec;36(6). Retrieved from https://conbio.onlinelibrary.wiley.com/doi/pdfdirect/10.1111/cobi.13970?utm_sq=gxlzdwfgsr.

[79] Taskforce on Scaling Voluntary Carbon Markets - Final Report. (2021). Retrieved from https://www.iif.com/tsvcm.

[80] Carbon standards typically certify projects for limited periods of time (5-10 years), so in principle it is possible to update accounting parameters to align with national methods and countries' forest reference emission levels (FREL).

[81] Verra: Consolidated REDD Methodology (under development, expected release in 2023). Retrieved December 8, 2022, from https://verra.org/methodologies/redd-methodology/

[82] Atmadja at al. (2022)

03

Conclusions

The results presented here suggest that carbon markets can play an important role in unlocking NbS mitigation potential globally, up to 2.7 $GtCO_2e$ yr^{-1} (2.0-3.6) by 2030 and 4.2 $GtCO_2e$ yr^{-1} (3.2-5.1) by 2050, thereby having the potential to deliver 10-12% of the mitigation needed by 2030 to be on track to reach global net zero by 2050.[83] However, carbon markets are not a silver bullet. Our estimates of available mitigation potential suggest that, even when measures are taken to facilitate carbon market investments, markets alone are insufficient to fully deliver the NbS mitigation potential of 8.5 $GtCO_2e$ yr^{-1} across the countries and activities assessed in this study over the next three decades.[84] As a result, it is important to leverage other financial instruments and policy interventions in parallel.

To reach 2.7 $GtCO_2e$ yr^{-1}, global carbon markets would need to grow by a factor of 17 by 2030. This steep increase in supply represents a compound annual growth rate of 37%. In terms of activities, Agriculture has the potential to deliver the bulk of this carbon market potential, with 43% of the total mitigation potential in 2030, followed by Avoided Deforestation (32%), Afforestation/Reforestation (11%), Improved Forest Management (7%), and the Restoration and Conservation of Wetlands (7%). Despite its potential, Agriculture in particular must overcome numerous challenges, most notably related to developing cost-effective MRV systems, addressing cultural barriers, and solving issues related to additionality.

Our study reveals that, to leverage carbon markets' NbS mitigation potential fully, it is important to continue to remove a range of political, economic, social, and legal barriers faced by investors and project developers. The available global NbS mitigation potential was reduced by 35% after accounting for the business and policy climate and land tenure insecurity. Improvements in these areas hold the potential of unlocking substantial additional mitigation potentials via future carbon market activities.

This study exemplifies the risks of approaching the supply of NbS mitigation potential from a price-centric perspective alone. Supply studies should attempt to capture, on the one hand, the different political, economic, social, and legal barriers that limit the implementation of NbS activities through carbon market channels. On the other hand, it is important to capture spatial restrictions in the form of locked-in land uses, which outline areas likely not to be accessible for carbon markets, either because there is another activity currently operating there or because the area may not satisfy additionality criteria.[85] The latter restrictions were relatively minor for some countries (e.g., Kenya[86]) but have been found to be material for others (e.g., Colombia).[87] The methodological approach presented in this report is a first attempt to reflect more realistically the on-the-ground limitations faced by project developers today.

While our analysis has focused on the mitigation impact various NbS activities can deliver, it is important to recognize that NbS investments can unlock a broad array of co-benefits, besides the pure GHG emission reductions. Co-benefits typically associated with NbS, which are context specific and require careful planning (see **Annex**, **Section 4.8**), include enhanced biodiversity, environmental health, human health, food security, and livelihoods of local communities, the (economic) value of which is paramount.

Further efforts are needed to produce high-quality, locally relevant data. An enhanced understanding of local restrictions to carbon project development may be obtained as spatial data becomes available across

[83] Considering the implementation gap of 23-27 $GtCO_2e$ as per the Climate Action Tracker: Climate Action Tracker, November 2022. Retrieved November 30, 2022, from https://climateactiontracker.org/global/cat-emissions-gaps/

[84] Roe et al. (2021).

[85] See Sections 4.4 and 4.5 for methodological details on how these spatial restrictions were considered.

[86] See Kenya technical report: Landholm, D., Bravo, F., Palmegiani, I., Streck, C., Omuko-Jung, L., et al. (2022). Unlocking nature-based solutions through carbon markets in Kenya - Technical Report. Climate Focus. Retrieved from https://climatefocus.com/publications/unlocking-nature-based-solutions-through-carbon-markets-in-kenya/

[87] See Colombia technical report: Landholm, D., Bravo, F., Streck, C., Martinez, G., Castro, J. P., Cote, L., et al. (2022). Unlocking nature-based solutions through carbon markets in Colombia - Technical Report. Climate Focus. Retrieved from https://climatefocus.com/wp-content/uploads/2022/09/Unlocking-Nature-based-Solutions-Colombia-Technical-Report-V1.1.pdf.

different types of land ownership (private, public, community, etc.). Currently, this data is not consistently available across jurisdictions, but when available, could further improve our understanding of carbon market limitations – and opportunities – on the ground.

Finally, the demand side of the market also presents substantial uncertainty as illustrated by the moderate drop in retirements observed in 2022.[88] Although carbon markets will evolve over time as a function of supply and demand, at present it is unclear how many companies will choose to implement efforts beyond their net-zero targets, i.e., to use carbon credits today as part of their climate change mitigation strategies, or how SBTi recommendations on Beyond Value Chain Mitigation[89] may ultimately affect buyers' appetite for purchasing carbon credits as part of their climate communication strategies.

[88] Climate Focus (2022). VCM Dashboard. Retrieved, from here

[89] SBTi (2021): SBTi corporate net-zero standard. Retrieved from: https://sciencebasedtargets.org/resources/files/Net-Zero-Standard.pdf

04

Annex

4.1 Historical VCM supply (2010-2022 Q3) (related to Section 1)

We assessed publicly available project and issuance databases from Verra's Voluntary Carbon Standard (VCS), Gold Standard (GS), American Carbon Registry (ACR), Climate Action Reserve (CAR), and Plan Vivo, and analyzed data from 2010-2022 Q3 to determine the activity types of projects registered, as well as the vintage and issuance years of the volumes issued.[90] Collectively, the six standards account for a vast majority of transactions taking place in the voluntary carbon market today (about 94% of the transacted volumes in 2021)[91], allowing us to present an accurate picture of the current state of the voluntary offset market.

The format of each registry differs in terms of details reported as well as the categorization of project types. Therefore, we organized all available data according to the same five categories (Agriculture, Afforestation/Reforestation, Avoided Deforestation, Improved Forest Management, and the Conservation and Restoration of Wetlands) to allow for a comparative analysis across the standards. This categorization of NbS project types is presented through **Table 2 – Table 5**.

Table 2: Methodologies used in the projects under the standards GS and VCS, and the equivalent category nomenclature used in this report, i.e., Agriculture, Afforestation/Reforestation, Avoided Deforestation, Improved Forest Management, and the Conservation and Restoration of Wetlands.

Methodologies GS&VCS	Methodology name	Group	Category	Sub-category
AMS-III.AU.	Methane emission reduction by adjusted water management practice in rice cultivation --- Version 4.0	NbS	Avoided emissions	Agriculture
AR-ACM0001	Afforestation and reforestation of degraded land --- Version 5.2.0	NbS	Removal	Afforestation/Reforestation
AR-ACM0002	Afforestation or reforestation of degraded land without displacement of pre-project activities --- Version 1.1.0	NbS	Removal	Afforestation/Reforestation
AR-ACM0003	Afforestation and reforestation of lands except wetlands --- Version 2.0	NbS	Removal	Afforestation/Reforestation
AR-AM0002	Restoration of degraded lands through afforestation/reforestation	NbS	Removal	Afforestation/Reforestation
AR-AM0003	Afforestation and reforestation of degraded land through tree planting, assisted natural regeneration and control of animal grazing ---Version 4.0	NbS	Removal	Afforestation/Reforestation
AR-AM0005	Afforestation and reforestation project activities implemented for industrial and/or commercial uses --- Version 4.0	NbS	Removal	Afforestation/Reforestation
AR-AM0007	Afforestation and Reforestation of Land Currently Under Agricultural or Pastoral Use --- Version 5.0	NbS	Removal	Afforestation/Reforestation
AR-AM0014	Afforestation and reforestation of degraded mangrove habitats --- Version 3.0	NbS	Removal	Wetlands

[90] Project and issuance data was pulled from the following sources:
Verified Carbon Standard (2022) Project Registry. Retrieved from https://bit.ly/32OLWkJ
Gold Standard (2022) Impact Registry. Retrieved from https://bit.ly/3cidwJX
American Carbon Registry (2022) Public Registry. Retrieved from https://bit.ly/3iQYi19
Climate Action Reserve (2022) Voluntary Offset Project Registry. Retrieved from https://bit.ly/2RKxLXi
Plan Vivo (2022). IHS Markit registry. Available here

[91] Forest Trends' Ecosystem Marketplace (2021) State of Voluntary Carbon Markets 2021: Markets in Motion. Retrieved from https://bit.ly/3AvFmx0.

AR-AMS0001	Simplified baseline and monitoring methodologies for small-scale A/R CDM project activities implemented on grasslands or croplands with limited displacement of pre-project activities --- Version 6.0	NbS	Removal	Afforestation/Reforestation
AR-AMS0002	Simplified baseline and monitoring methodologies for small-scale afforestation and reforestation project activities under the CDM implemented on settlements --- Version 2.0	NbS	Removal	Afforestation/Reforestation
AR-AMS0003	Afforestation and reforestation project activities implemented on wetlands --- Version 3.0	NbS	Removal	Wetlands
AR-AMS0004	Simplified baseline and monitoring methodology for small-scale agroforestry - afforestation and reforestation project activities under the clean development mechanism --- Version 2.0	NbS	Removal	Agriculture
AR-AMS0005	Simplified baseline and monitoring methodology for small-scale afforestation and reforestation project activities under the clean development mechanism implemented on lands having low inherent potential to support living biomass --- Version 2.0	NbS	Removal	Afforestation/Reforestation
AR-AMS0006	Simplified baseline and monitoring methodology for small-scale silvopastoral - afforestation and reforestation project activities under the clean development mechanism --- Version 1.0	NbS	Removal	Agriculture
AR-AMS0007	Afforestation and reforestation project activities implemented on lands other than wetlands --- Version 3.1	NbS	Removal	Afforestation/Reforestation
GS GHG A.R GHG Emissions Reduction Sequestration v1.	GHG Emissions Reduction Sequestration	NbS	Removal	Afforestation/Reforestation
VM00015	Avoided Unplanned Deforestation	NbS	Avoided emissions	Avoided deforestation
VM0003	Methodology for Improved Forest Management through Extension of Rotation Age, v1.2	NbS	Removal	Improved forest management
VM0004	Methodology for Conservation Projects that Avoid Planned Land Use Conversion in Peat Swamp Forests, v1.0	NbS	Avoided emissions	Wetlands
VM0005	Methodology for Conversion of Low-productive Forest to High-productive Forest, v1.2	NbS	Removal	Improved forest management
VM0006	Carbon Accounting for Mosaic and Landscape-scale REDD Projects, v2.2	NbS	Avoided emissions	Avoided deforestation
VM0007	REDD+ Methodology Framework (REDD-MF)	NbS	Avoided emissions	Avoided deforestation
VM0009	Methodology for Avoided Ecosystem Conversion	NbS	Avoided emissions	Wetlands
VM0010	Improved Forest Management: Conversion from Logged to Protected Forest	NbS	Removal	Improved forest management
VM0011	Methodology for Calculating GHG Benefits from Preventing Planned Degradation, v1.0	NbS	Avoided emissions	Improved forest management
VM0012	Improved Forest Management in Temperate and Boreal Forests (LtPF), v1.2	NbS	Removal	Improved forest management
VM0015	Avoided Unplanned Deforestation	NbS	Avoided emissions	Avoided deforestation
VM0017	Adoption of Sustainable Agricultural Land Management	NbS	Removal	Agriculture
VM0026	Methodology for Sustainable Grassland Management (SGM)	NbS	Removal	Agriculture

VM0032	Methodology for the Adoption of Sustainable Grasslands through Adjustment of Fire and Grazing	NbS	Removal	Agriculture
VM0034	British Columbia Forest Carbon Offset Methodology, v1.0	NbS	Removal	Improved forest management
VM0037	Implementation of REDD+ Activities in Landscapes Affected by Mosaic Deforestation and Degradation	NbS	Avoided emissions	Avoided deforestation

ACR, CAR, Plan Vivo:

In contrast to GS and VCS, the ACR, CAR, and Plan Vivo databases do not include the methodologies used in each project. However, they do include detailed and accurate project categorizations. The following tables show the project types in the ACR, CAR, and Plan Vivo databases, which were used as input for the categorization, applying the following equivalencies:

Table 3: Project categories used by the standard ACR and the equivalent category nomenclature used in this report, i.e., Agriculture, Afforestation/Reforestation, Avoided Deforestation, Improved Forest Management, and the Conservation and Restoration of Wetlands.

ACR Category	Group	Category	Sub-category
Agricultural Land Management	NbS	Avoided emissions	Agriculture
Forest Carbon - Other	NbS	Removal	Afforestation/Reforestation
Forest Carbon - Improved forest Management	NbS	Removal	Improved Forest Management
Wetland Restoration	NbS	Removal	Afforestation/Reforestation

Table 4: Project categories used by the standard CAR and the equivalent category nomenclature used in this report, i.e., Agriculture, Afforestation/Reforestation, Avoided Deforestation, Improved Forest Management, and the Conservation and Restoration of Wetlands.

CAR Categories	Group	Category	Subcategory
Forestry - MX	NbS	Removal	Afforestation/Reforestation
Avoided Conversion	NbS	Avoided emissions	Wetlands
Improved Forest Management	NbS	Removal	Improved forest management
Avoided Grassland Conversion	NbS	Avoided emissions	Wetlands
Conservation-Based Forest Management	NbS	Removal	Improved forest management
Reforestation	NbS	Removal	Afforestation/Reforestation

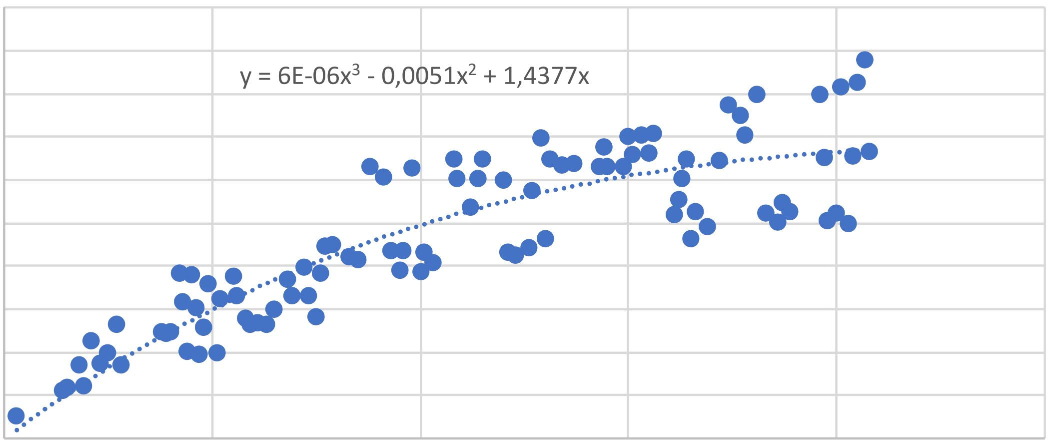
Table 5: Project categories used by the standard Plan Vivo and the equivalent category nomenclature used in this report, i.e., Agriculture, Afforestation/Reforestation, Avoided Deforestation, Improved Forest Management, and the Conservation and Restoration of Wetlands.

Plan Vivo category	Group	Subcategory
Forest Conservation & Avoided Deforestation	Labelled on a project basis	Labelled on a project basis
REDD	Avoided emissions	Avoided deforestation
Improved forest management	Removal	Improved Forest Management
Afforestation / Reforestation	Removal	Afforestation/Reforestation
Forest Restoration	Labelled on a project basis	Labelled on a project basis
Reduced emissions from deforestation & degradation	Avoided emissions	Avoided deforestation
Agriculture land management	Removal	Agriculture
Forest	Labelled on a project basis	Labelled on a project basis

4.2 Methodology (related to Section 2)

To estimate how much mitigation potential can be unlocked by carbon markets, we combined unpublished IPCC regional Marginal Abatement Cost Curves (MACC), produced by MESSAGE-GLOBIOM, an integrated assessment model (IAM), with the latest country data on Nature-based Solutions (NbS) mitigation potential from Roe et al. (2021). This paper provides available mitigation estimates ("cost-effective mitigation") for 20 different NbS (USD100/tCO_2e). For each of the five considered activities (Avoided Deforestation, Afforestation/Reforestation, Agriculture[92], the Conservation and Restoration of Wetlands, and Improved Forest Management), we fitted a function to the MACC output of MESSAGE-GLOBIOM model. The output of this model provides how much mitigation is unlocked for different prices (see example of Agriculture for Africa in Figure 10). We used the shape of the regional MACC and apply it to the Roe et al. (2021)'s country-level mitigation data estimate (USD100/tCO_2e) to extract how much can be unlocked at lower prices.

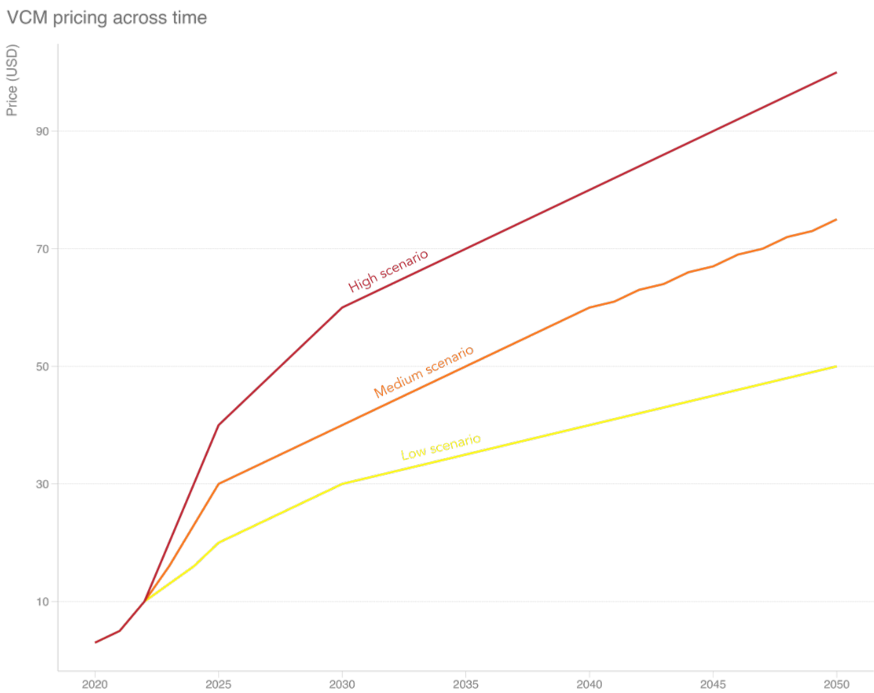
Figure 10: Example of a fitted function for a Marginal Abatement Cost Curve (MACC) based on MESSAGE-GLOBIOM's integrated assessment model (IAM). This curve refers to the Afforestation/Reforestation activity for Africa.



[92] The Agriculture activity includes mitigation potential from activities that reduce emissions and/or remove CO_2 from the atmosphere and store it in the soil and biomass. Specifically, the following activities are considered: Enteric fermentation, manure management, improved rice production, nutrient management, soil carbon sequestration on grasslands, soil carbon sequestration on croplands, agroforestry, and biochar

Next, we considered three price scenarios (**Figure 11**). Given the long timeframe considered (until 2050), a simple and transparent scenario-based approach is preferred over modeling specific price forecasts, which is particularly complex in the very uncertain carbon market environment. Combining these wide price projection ranges with the information above, we obtained a first estimate of how much mitigation potential can be unlocked in any given country for each of the five activities, which considers both available NbS mitigation potential and possible price scenarios.

Figure 11: Price projections considered (low, medium, high).



4.3 Feasibility factors

NbS project implementation does not solely consider costs, as numerous other, typically ignored, dimensions can act as barriers for the uptake of projects. Political, institutional, social, and technological dimensions are important. We found that there is a significantly positive correlation between Roe et al. (2021)'s NbS country feasibility scores, which includes many of these dimensions, and project uptake[93] across all countries engaged in VCM.

We developed a tailored feasibility scoring system that reflects three distinct carbon market investment and implementation barriers. Specifically, we used the business and investment freedom indexes from the Heritage Foundations as a proxy of "ease of doing business," reflecting the need for countries to remove barriers to external investments. In addition, we considered the same political feasibility factors used in Roe et al. (2021). Political feasibility includes World Bank indicators of Voice and Accountability, Political Stability and Absence of Violence/Terrorism, Government effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption. Finally, for land tenure security we used the International Property Rights Index.[94]

We combined the three parameters described above (i.e., ease of doing business, political index, and land tenure) to calculate the feasibility score for each of the 214 countries in the dataset

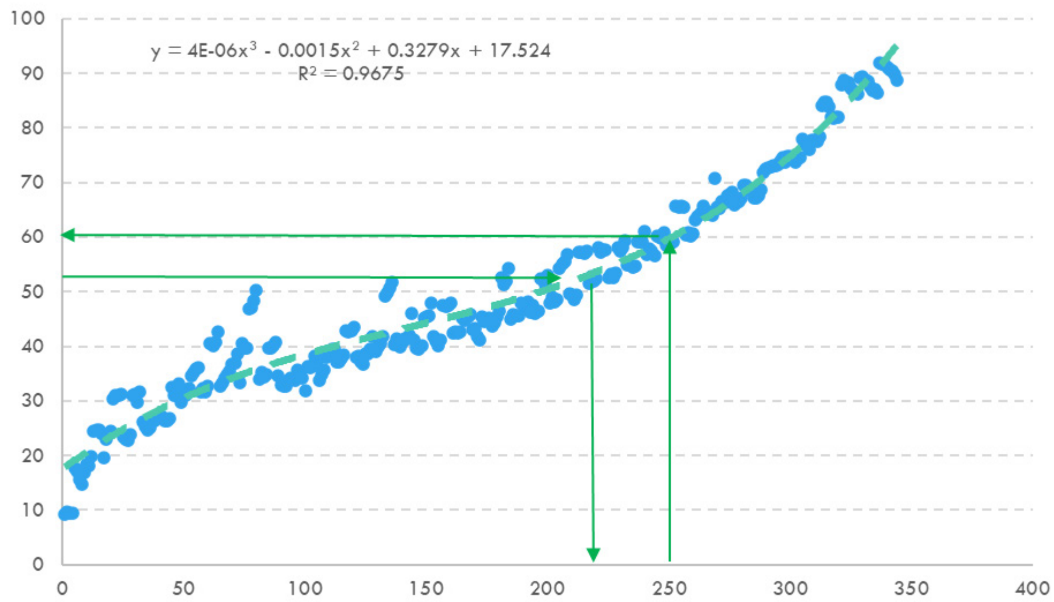
[93] We measured project uptake as project*years, i.e., the number of VCM NBS projects a given country times the number of years each project has been running.

[94] Property Rights Alliance. (2021). International Property Rights Index. Retrieved from http://www. internationalpropertyrightsindex.org.

and year.[95] We used historical data of these three variables from 2013 to 2020 to estimate how feasibility factors may evolve over time. For this purpose, we divided the countries into 43 groups of five to six countries, calculated the feasibility factors for each country and year, then averaged the yearly score among countries in each group. We then sorted the country groups according to their average score in 2013 and values in each group according to year. As a result, we obtain a sequence of 344 scores (i.e., 43 groups by eight years per group), indexed from 0 to 343.

Figure 12 displays how the average feasibility scores of these groups (y axis) change over time (x axis), i.e., the 344 data points. Based on historic data, as observed, feasibility scores are expected to gradually increase over time, albeit at different rates, depending on where a country starts on the development pathway curve.

Figure 12: Modelled evolution of feasibility scores over time. Y axis represents feasibility scores, x axis years. Green lines (with arrows) highlight the process: we have the initial feasibility score for Kenya (53), obtain the initial time value (x axis); then we return x+30 years to the equation to obtain the feasibility factor in 2050 (60).



To obtain the feasibility score in 2050 for an individual country, we proceed as follows along the fitted function shown in **Figure 12**: we consider the starting feasibility score of the country at present day (2020), e.g., Kenya (53), and derive the corresponding time index on the x axis. We then obtain the final feasibility score as the y value corresponding to x+30, which for Kenya is 60. Kenya therefore experiences a growth of 12.4% in their feasibility score over this time period.

The final step is to transform the calculated feasibility scores into percentage values, which are used as filters to discount the mitigation potential of each country. This was done by assigning scores from 0 to 100 to each country for every year (i.e., the lowest scoring country receives 0 and the highest 100). Under this assumption the top scoring feasibility country (100%) has no barriers, and no mitigation potential is discounted in the model. In contrast, the worst scoring country receives 0%, i.e., no mitigation is unlocked through carbon markets in this country due to high barriers.

95 Individual feasibility scores are first normalized (0-100), then averaged across the three variables to obtain a final feasibility score.

Continuing with the example of Kenya, the feasibility filter goes from 53.1% in 2020 to 67,8% in 2050. This means that 46.9% and 32.2% from Kenya's NbS mitigation potential in 2020 and 2050 are discounted from the model, respectively.

4.4 Spatially explicit mitigation potential maps

In a final step, we considered areas where it is very difficult to develop carbon market projects, due to existing on-the-ground limitations. We refer to these as "locked-in land uses." The following activities are considered: economic concessions[96], ongoing and planned mining activities[97], the extraction of oil and gas[98], and protected areas.[99] The location, size and productivity of extractive sites serve as proxies for the portions of terrain covered by locked-in land uses. Overall, our approach holds the underlying assumption that investors and project developers will prefer to invest in areas that are not used by or committed to extractive industries.

We used existing spatially explicit maps on mitigation potential per activity for Avoided Deforestation, Afforestation/Reforestation, and Agriculture, and estimated what percentage of the potential falls within these locked-in areas. This percentage is then applied to the country-level model output to provide a conservative estimate on what is realistically available for NbS mitigation via carbon markets. The final maps are also used to highlight where the potential for different activities lies (**Figure 9** and **Figure 18**).

For Avoided Deforestation, data is obtained directly from Koh et al. (2021).[100] These authors address key VCS criteria, including additionality, to model and map investible forest carbon across the tropics; for Afforestation/Reforestation potential we consider carbon accumulation potential from natural forest regrowth in reforestable areas. We used data from Cook-Patton et al. (2020), filtered to include only reforestable areas as defined by Griscom et al. (2017).[101] This map is not specific to carbon markets, but presents overall potential for the activity. Finally, for Agriculture potential we used the recently released Global Soil Sequestration Potential (GSOCseq) Map from FAO,[102] using scenario 3 and compared it to the business as usual (BAU) scenario. Using a more

96 Land Coalition (ILC), Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Centre for Development and Environment (CDE), German Institute of Global and Area Studies (GIGA) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). (2022). Land Matrix Public Database on Land Deals. Retrieved from https://landmatrix.org/.

97 Mines footprints provided in Maus et. Al. (2021). Global-scale mining polygons (Version 1). PANGAEA, https://doi.org/10.1594/PANGAEA.910894. These footprints were used to identify the for the location of active mining projects. Further, we calculated the ratio between mine footprints and the respective mining concessions (as provided on Global Forest Watch (n.d). Retrieved from https://www.globalforestwatch.org/) to estimate the size of concessions where the mine footprint is known but not the respective concession area.

98 Data on location and production of extraction facilities are provided by the Global Energy Monitor [https://globalenergymonitor.org/]. Production of each facility is used to estimate the size of the respective land concession.

Land Matrix: Public database on land deals (n.d.). Retrieved from https://landmatrix.org/.

Mines footprints provided in Maus et al. (2021) were used to identify the for the location of active mining projects. Further, we calculate the ratio between mine footprints and the respective mining concessions as provided on Global Forest Watch, to estimate the size of concessions where the mine footprint is known but not the respective concession area. Maus, V., Giljum, S., Gutschlhofer, J., da Silva, D. M., Probst, M., Gass, S. L. B., et al. (2020). Global-scale mining polygons (Version 1) [Data set]. PANGAEA. Retrieved October 11, 2022, from https://doi.pangaea.de/10.1594/PANGAEA.910894. Global Forest Watch. (n.d.). "Mining concessions." Retrieved from www.globalforestwatch.org.

IUCN and UNEP-WCMC (2022), The World Database on Protected Areas (WDPA) line], Sept/2022, Cambridge, UK: UNEP-WCMC. Available at: www.protectedplanet.net.

99 IUCN and UNEP-WCMC (2022), The World Database on Protected Areas (WDPA) [On-line], Cambridge, UK: UNEP-WCMC. Available at: www.protectedplanet.net. Accessed through Global Forest Watch in March, 2020. www.globalforestwatch.org

100 Koh, L. P., Zeng, Y., Sarira, T. V., & Siman, K. (2021). Carbon prospecting in tropical forests for climate change mitigation. Nature Communications, 12(1), 1–9.

101 Cook-Patton, S. C., Leavitt, S. M., Gibbs, D., Harris, N. L., Lister, K., Anderson-Teixeira, K. J., et al. (2020). Mapping carbon accumulation potential from global natural forest regrowth. Nature, 585(7826), 545–550.

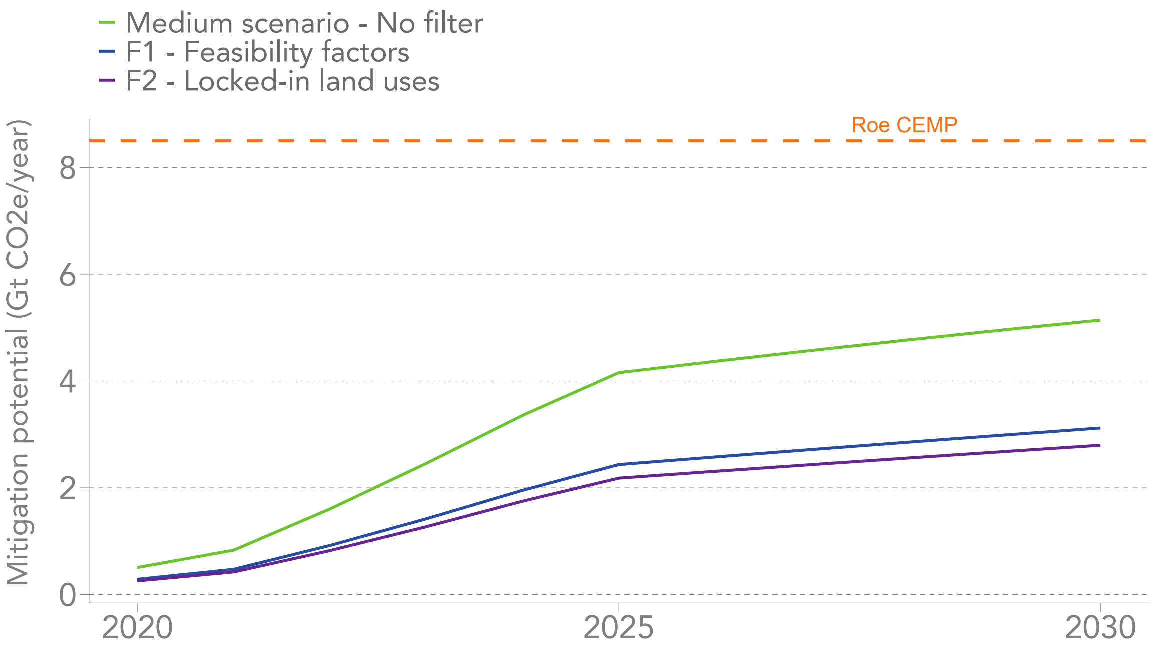
Griscom, B. W., Adams, J., Ellis, P. W., Houghton, R. A., Lomax, G., Miteva, D. A., et al. (2017). Natural climate solutions. Proceedings of the National Academy of Sciences, 114(44), 11645–11650.

102 FAO. (2022). Global soil organic carbon sequestration potential map (GSOCseq v1.1). Retrieved from http://www.fao.org/documents/card/en/c/cb2642en.

pessimistic scenario (e.g., scenario 1) would reduce slightly the values presented in the map but does not affect the distribution of where the potential is. Similar to Afforestation/Reforestation, this map is not specific to carbon markets, but presents the overall distribution potential for the activity.

All three potential maps are then processed to account for locked-in land uses where leveraging carbon markets is deemed difficult. This provides not only a final map of where the activity may be developed, but also the second feasibility filter (%) that is applied to the country model. After accounting for economic, feasibility, and land tenure barriers, the model then accounts for locked-in land uses by applying a percentage reduction that is informed by these spatially explicit maps.

Figure 13: Visual description of methodological process, displaying a medium price scenario (green). The blue line shows the mitigation output after discounting mitigation due to feasibility barriers, while the purple line shows the final potential available after accounting as well for locked in land uses. The dashed line depicts the cost-effective mitigation potential (CEMP).[103]



4.5 Methodological uncertainty

Providing estimates on how much NbS is available globally is fraught with uncertainty. We quantify two main sources of uncertainty within our approach: firstly, we consider three different price scenarios (Figure 11). Secondly, within the evaluation of "locked in land uses" we consider three different scenarios for the inclusion of protected areas:

1. Projects cannot be developed in any protected area,

[103] Roe et al., 2021

2. Projects cannot be developed in International protected areas of high importance, but can be developed in others, and

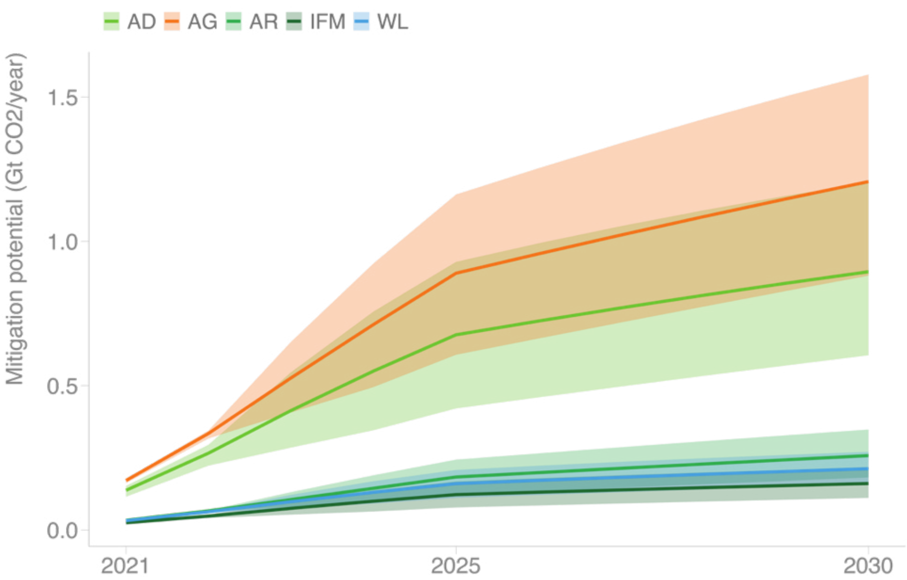
3. Projects can be developed in all protected areas.

The question of whether to include or not protected areas relates to the question of additionality – is the mitigation provided by an Avoided Deforestation project in a protected area additional? The answer to this question is that it depends across different geographies; we found that this additionality question is not relevant in protected areas of Kenya (i.e., deforestation occurs within its boundaries and there is ample support for developing carbon projects there across stakeholders), whereas the situation in Colombia is very different. While technically it is possible to develop VCM projects in protected areas in Colombia, numerous barriers exist in practice: first, protected areas are publicly owned land, and bureaucratic procedures may discourage the pursuit of VCM activities; second, there is a generalized perception held by public officials that VCM projects in PAs don't comply with additionality requirements; finally, Colombia may have preference to use these areas to achieve its NDC goals.[104]

At a global scale, given that it is very challenging to determine this situation for each individual country we considered all three possibilities.

The three different price scenarios and three different protected area scenarios produce nine different mitigation data points per year for each activity and for each country. The results presented throughout the document and in **Figure 14** below highlight the mean of these nine scenarios together with the minimum and maximum estimates.

Figure 14: Estimates of mitigation potential available for five NbS (Nature-Based Solutions) through carbon markets. All these estimates should be interpreted as upper limit estimate, with the uncertainty ribbons reflecting the methodological uncertainty.



[104]For more information on Kenya and Colombia, consult Climate Focus' country reports on Kenya and Colombia:

Landholm, D., Bravo, F., Palmegiani, I., Streck, C., Omuko-Jung, L., et al. (2022). Unlocking nature-based solutions through carbon markets in Kenya - Technical Report. Climate Focus. Retrieved from https://climatefocus.com/publications/unlocking-nature-based-solutions-through-carbon-markets-in-kenya/

Landholm, D., Bravo, F., Streck, C., Martinez, G., Castro, J. P., Cote, L., et al. (2022). Unlocking nature-based solutions through carbon markets in Colombia - Technical Report. Climate Focus. Retrieved from https://climatefocus.com/wp-content/uploads/2022/09/Unlocking-Nature-based-Solutions-Colombia-Technical-Report-V1.1.pdf.

4.6 Limitations

Forecasting carbon markets' potential over a long timeframe for a varied set of NbS is fraught with challenges that reflects on some limitations of our analysis.

First, the defined price trajectories, the used MACCs, and the filters (feasibility and locked in land uses) do not capture some additional activity-specific constraints. For instance, our model shows Agriculture as the activity with most potential; however, important technical barriers related to measuring, reporting and verification (MRV) need to be overcome for carbon markets to leverage Agriculture's full potential. A lot of effort is currently placed on solving these barriers, but the outcome is yet unclear.[105] It is also unclear how future changes in carbon market standard rules will affect these estimates. For instance, renewable energy projects used to represent a large share of carbon markets but are no longer considered additional and have been excluded by some carbon market standards (except for Least Developed Countries).

Second, our model uses regional MACCs derived from IAMs for five different NbS activities. The model takes the shape of the regional MACC and applies it to the country-specific mitigation potential presented by Roe et al. (2021), i.e., the cost-effective mitigation potential unlocked at USD100/tCO_2e. Although this approach is not expected to deviate substantially from an approach that gathers country-level costs, the accuracy can certainly be improved in the future by using local data.

Third, proving additionality is an important element for the development of carbon projects. Although additionality is not explicitly treated in our model, the underlying NBS mitigation potentials used as a starting point from Roe et al. (2021) do cover it implicitly at a country scale. Namely, the underlying studies where this mitigation is calculated from (see Table 1 in Roe et al., 2021) typically consider the mitigation potential in relation to the continuation of business-as-usual activities. Hence, although it would be preferable to have a gauge of carbon market-specific additionality of these activities, and how they vary across activities, the additionality restriction is likely covered to a large extent.

Fourth, the estimation of the portion of area occupied by locked-in land uses is unlikely to perfectly match the shape and size of mining, oil and gas concessions in the country. As spatially explicit information becomes available on these land uses, the accuracy of the model outputs can be improved. However, at a country scale, this is expected to be a minor source of uncertainty.

Fifth, our estimates of available mitigation potentials through carbon markets only cover the countries currently engaged in VCM with NbS projects. However, it is likely that more countries will join over time and hence a larger amount may become available.

Sixth, individual country policies are not considered in the model but can naturally affect the outcome in different ways. Some policy changes may stimulate carbon market growth while others might inhibit market growth if certain GHG reduction or removal practices are mandated or strongly incentivized, reducing the case for additionality. For instance, if countries align their implementation action to match recent no-deforestation pledges, the available mitigation potential from Avoided Deforestation projects after 2030 may be limited.

Finally, carbon market prices will evolve over time as a function of supply and demand. Regarding the latter, however, there are still a lot of uncertainties regarding how many companies will go

[105] For an overview of technical challenges related to measuring, monitoring, and verifying soil organic carbon changes, see: European Commission, Directorate-General for Climate Action, Radley, G., & Keenleyside, C. (2021). Technical guidance handbook: setting up and implementing result based carbon farming mechanisms in the EU. Retrieved from https://data.europa.eu/doi/10.2834/12087.

beyond net-zero targets. The volume of credits generated by neutrality claims may be even larger than target-year net-zero claims. Hence, until this becomes clearer the uncertainty around demand is very large over a 30-year forecasting period. Here, we preferred to lay a wide range of price scenarios to gauge the effect under different scenarios. We expect currently that demand will quickly outpace supply, and therefore addressing country supply barriers and current labor shortage is urgently needed.

4.7 Other figures and tables

Figure 15: Cost effective (<US$100/t$CO_2$e) mitigation potential of land-based mitigation available for different instruments (including voluntary carbon markets). Country-level mitigation potential available in the bottom 30 countries with VCM supply.

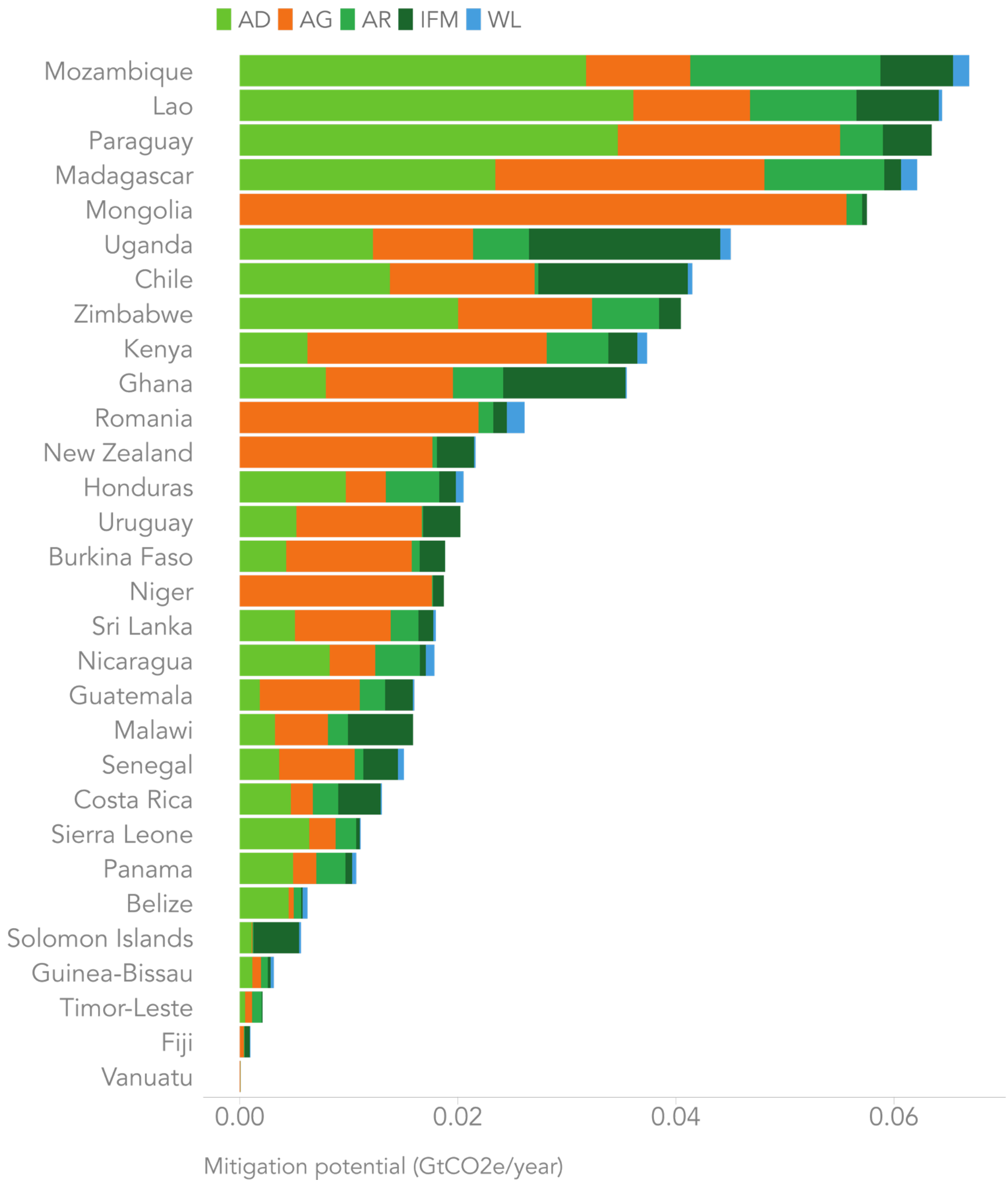


Figure 16: Estimates of mitigation potential for five NbS (Nature-Based Solutions) through carbon markets and their comparison to the reference "phased cost-effective mitigation potential (CEMP)." Phased CEMP uses Roe et al. (2021)'s updated mitigation values combined with Roe et al. (2019)'s proposed land-sector roadmap.[106]

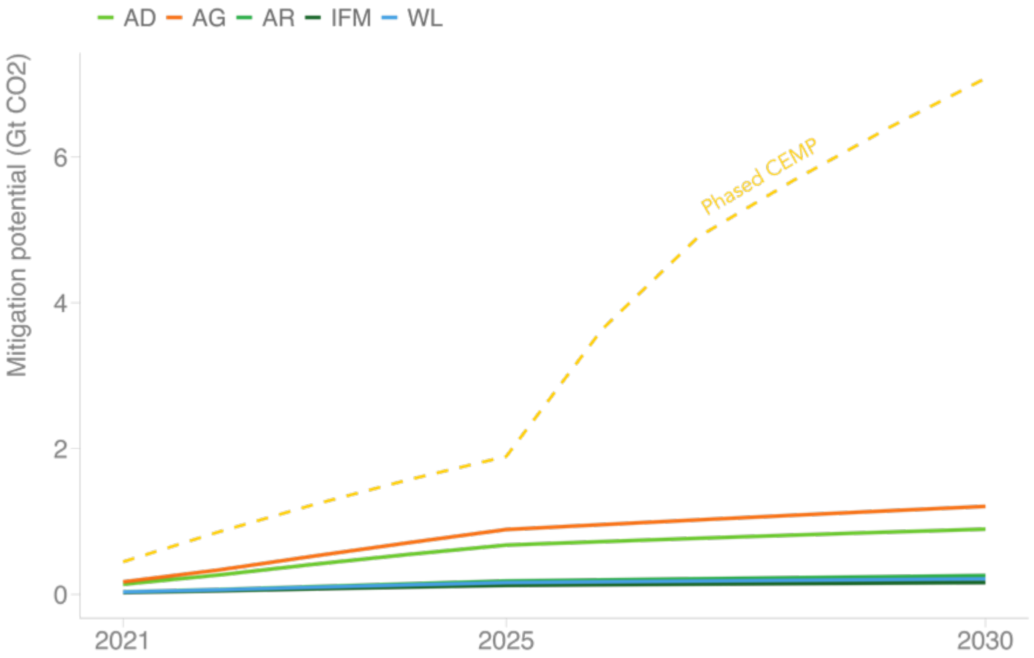
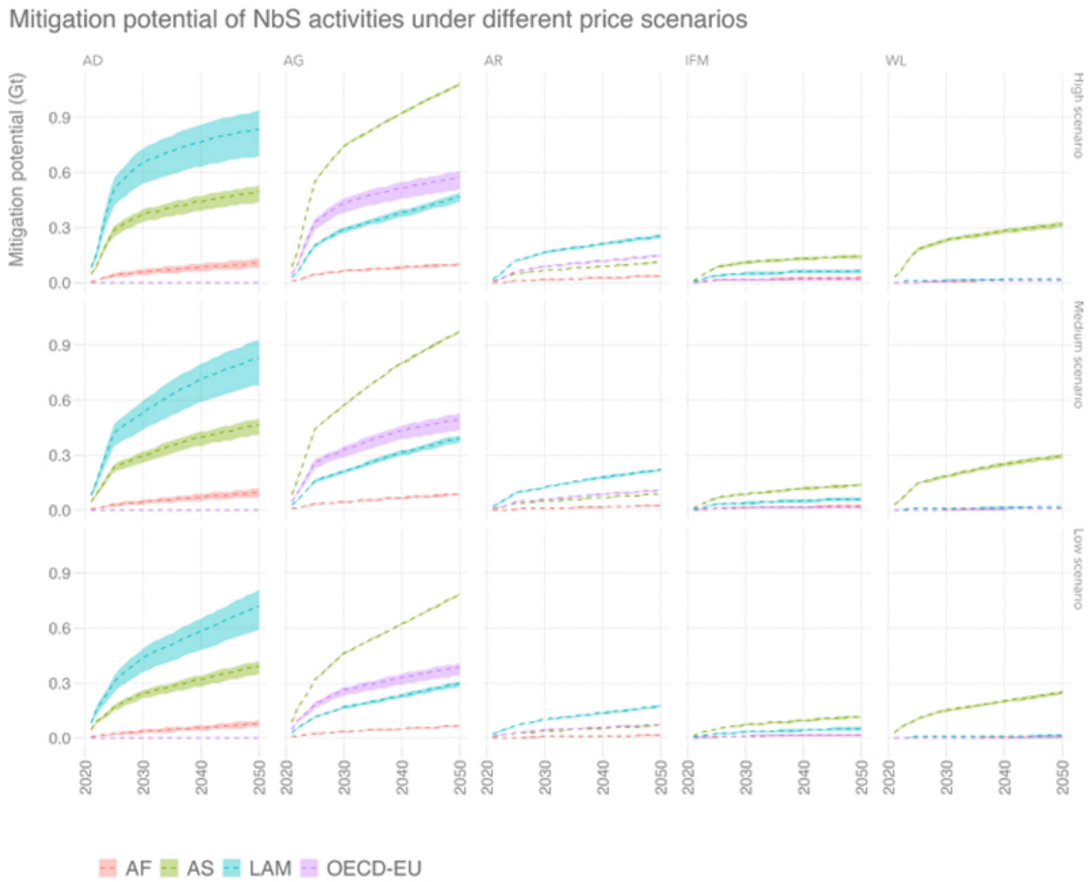


Figure 17: Mitigation potential of NbS activities (columns) from carbon markets under different price scenarios (rows). The uncertainty ribbon here relates to the three different locked in scenarios, namely whether all protected areas are considered, only international ones, or all protected areas.



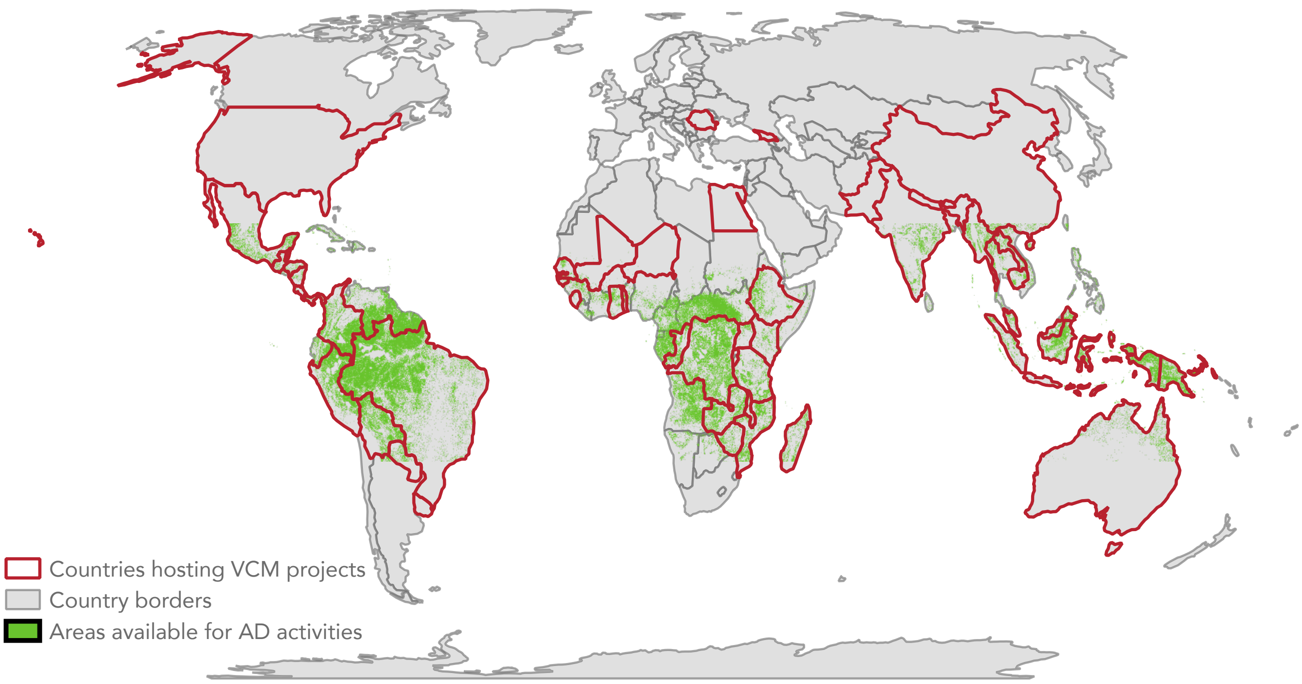
[106] See Figure 6c of Roe, S., Streck, C., Obersteiner, M., Frank, S., Griscom, B., Drouet, L., et al. (2019). Contribution of the land sector to a 1.5 C world. Nature Climate Change, 9(11), 817–828.

Table 6: Overview of the mitigation potential by 2030 ($MtCO_2e$ y-1) estimated for all countries hosting VCM projects. Avoided Deforestation (AD), Agriculture (AG), Afforestation/Reforestation (AR), Improved Forest Management (IFM), and Wetlands (WL).

Country	Estimated mitigation potential for 2030 ($MtCO_2e$/year)				
	AD	AG	AR	IFM	WL
Australia	0.02		1.69	15.30	2.58
Belize	1.52	0.13	0.20	0.04	0.17
Bolivia	12.95	1.03	0.78	0.06	0.03
Brazil	327.39	157.18	102.74	25.33	3.85
China	12.47	302.01	5.87	17.59	6.45
Congo, Dem. Rep.	7.93	0.54	0.55	0.25	0.15
Congo, Rep.	6.32	0.23	0.30	0.53	1.28
Colombia	83.87	12.38	7.71	2.09	1.69
Costa Rica	2.24	0.73	0.92	1.81	0.06
Egypt, Arab Rep.		4.41		0.04	0.00
Ethiopia	1.69	6.22	1.02	0.65	0.44
Georgia		1.67	0.48	1.01	0.00
Ghana	2.98	4.27	0.97	3.80	0.05
Guinea-Bissau	0.12	0.08	0.03	0.02	0.03
Guatemala	0.42	1.97	0.57	0.57	0.03
Honduras	2.99	0.97	1.39	0.46	0.24
Indonesia	187.62	46.41	19.66	47.25	167.80
India	9.33	211.66	13.62	14.91	0.53
Kenya	2.00	6.95	1.05	0.77	0.30
Cambodia	4.93	2.77	1.01	0.09	0.06
Lao PDR	6.61	1.83	1.42	1.43	0.06
Madagascar	5.09	5.23	1.33	0.30	0.33
Mexico	21.03	29.21	9.59	7.79	4.92
Mali	0.93	3.91		0.25	0.00
Myanmar	8.81	6.77	2.22	1.38	1.09
Mozambique	4.45	1.22	1.41	0.84	0.21
Malawi	0.65	1.04	0.24	1.08	0.00
Malaysia	43.88	7.56	4.24	5.78	15.06
Niger		3.96		0.22	0.00
Nicaragua	1.50	0.53	0.57	0.10	0.14
Pakistan		12.68	0.89	0.70	0.10
Panama	2.57	0.97	1.28	0.31	0.22
Peru	74.70	7.10	3.98	0.79	0.38
Papua New Guinea	30.84	0.45	2.74	2.23	0.41
Paraguay	11.72	6.18	1.30	1.47	0.00

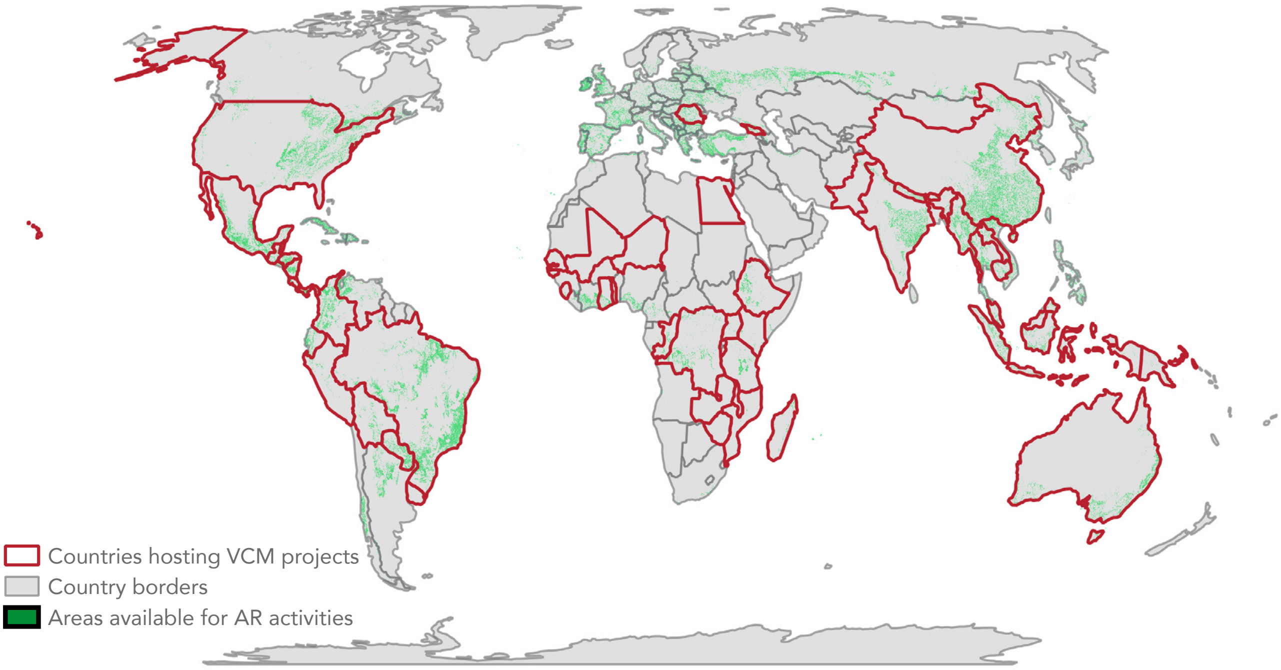
Romania		10.27	0.45	0.82	0.76
Senegal	1.05	2.08	0.16	0.82	0.18
Sierra Leone	1.23	0.43	0.21	0.06	0.02
Togo	0.37	0.76	0.18	0.07	0.00
Timor-Leste	0.10	0.12	0.15	0.02	0.00
Tanzania	9.68	5.38	2.61	1.35	1.15
Uganda	2.59	1.96	0.61	3.34	0.21
Uruguay		5.83	0.03	1.74	0.00
United States		329.84	61.51	30.67	1.21
Zambia	17.85	2.88	2.02	0.96	0.01
Zimbabwe	0.84	0.48	0.12	0.08	0.00

Figure 18: Global area of opportunity for Avoided Deforestation. Source: Koh et al. 2022.[107] The dataset has been modified to exclude locked in land uses, namely mining, oil and gas concessions, economic concessions, and international protected areas. Countries with existing VCM NbS issuances are outlined in red (countries with issuances of any NbS project type).



[107] Koh, L. P., Zeng, Y., Sarira, T. V., & Siman, K. (2021). Carbon prospecting in tropical forests for climate change mitigation. Nature Communications, 12(1), 1271.

Figure 19: Global area of opportunity for natural forest regrowth in reforestable areas (used as a proxy of Afforestation/Reforestation). Source from Cook-Patton et al. (2020)[108] filtered to include only reforestable areas as defined by Griscom et al. (2017).[109] The dataset has been modified to exclude locked in land uses, namely mining, oil and gas concessions, economic concessions, and international protected areas. Countries with existing VCM NbS issuances are outlined in red (countries with issuances of any NbS project type).



4.8 Co-benefits of NbS measures

Nature-based solutions are unique in that they can provide substantial climate mitigation while also contributing to various Sustainable Development Goals (SDGs) including enhancing biodiversity, environmental health (water, air, soil, resilience), food security, human health, and livelihoods. However, the impacts of NbS are highly context specific and the results from one NbS project is not universally applicable to others. The efficacy of climate mitigation, the provision of other benefits, and the potential risks or trade-offs of land-based measures largely depend on the type of activity undertaken, its geographic context (e.g., climate, ecosystem type, state of the land, land ownership, local community), and the deployment and management strategy taken over time (e.g., scale, method, species, complementarity with other measures and sectors).[110] Poorly planned and implemented land interventions, often with the sole purpose of maximizing climate mitigation, is likely to lead to adverse outcomes. Potential consequences of inappropriate projects may be considerable, negatively affecting biodiversity, sustainable development, and human wellbeing. Furthermore, there are various risks associated with climate change impacts and disturbances, GHG accounting, and transboundary effects.

[108] Cook-Patton, S. C., Leavitt, S. M., Gibbs, D., Harris, N. L., Lister, K., Anderson-Teixeira, K. J., et al. (2020). Mapping carbon accumulation potential from global natural forest regrowth. Nature, 585(7826), 545–550.; Griscom, B. W., Adams, J., Ellis, P. W., Houghton, R. A., Lomax, G., Miteva, D. A., et al. (2017). Natural climate solutions. Proceedings of the National Academy of Sciences, 114(44), 11645–11650.

[109] Griscom, B. W., Adams, J., Ellis, P. W., Houghton, R. A., Lomax, G., Miteva, D. A., et al. (2017). Natural climate solutions. Proceedings of the National Academy of Sciences, 114(44), 11645–11650.

[110] Smith, P., Adams, J., Beerling, D. J., Beringer, T., Calvin, K. V., Fuss, S., et al. (2019). Land-Management Options for Greenhouse Gas Removal and Their Impacts on Ecosystem Services and the Sustainable Development Goals. Annual Review of Environment and Resources, 44(1), 255–286.

Based on existing literature we summarize relevant benefits and risks for each of the five main NbS measures, identify relevant SDGs, and outline best practices that maximize co-benefits and limit trade-offs (**Table 6**). The protection of natural ecosystems presents particularly high co-benefits, preserving vital ecosystem services and helping maintain the carbon sequestration of the natural land sink. If lost, much of the carbon, biodiversity and ecosystem services from converted ecosystems are also irrecoverable through restoration by the 2050 timeframe for net zero targets.[111] Restoration of degraded ecosystems (particularly peatlands, coastal wetlands, and tropical forests), as well as carbon sequestration in agriculture (especially agroforestry and soil carbon management) also have the potential to deliver substantial co-benefits including improving livelihoods, agricultural yields, and resilience to climate change. On the other hand, A/R and restoration efforts using inappropriate species and methods (i.e., monoculture plantations) include risks to water availability, biodiversity, and food security. Afforestation of natural grasslands and drier biomes with monoculture plantations can produce particularly acute negative impacts and require remediation (tree removal) which cause carbon reversals.

Climate change, disturbances, and socio-political conditions can pose a major risk for the permanence of emission reductions and carbon removals from a majority of NbS interventions (**Table 7**). To date, permanence risks have been successfully managed by establishing buffer carbon pools as insurance for reversals. However, it is difficult to fully account for permanence risk, and thus the adequate size of buffer pools due to high uncertainties.

Other challenges related to NbS carbon projects include the method of GHG accounting, monitoring, reporting and verification (MRV), and leakage. The choice of baselines and/or reference levels and MRV standards could potentially inflate emission reductions, and thus the effectiveness of climate mitigation. Leakage, or the idea that emission reductions in one place may lead to increased emissions in another, is an inherent transboundary risk from NbS offsets.

The quality and success of each NbS project will ultimately depend on whether it was planned and implemented accounting for local climatic, environmental, and social conditions, considering cross-sectoral and transboundary impacts and spillover effects, maximizing other potential benefits, and minimizing any negative externalities and climatic and GHG accounting risks. VCM certifications, including those that validate non-climate impacts like the Climate, Community, and Biodiversity (CCB) Standards, are important for promoting quality projects. However, more work is needed to develop and prioritize land-based mitigation that truly deliver on the promise of nature-based solutions.

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[111] Goldstein, A., Turner, W.R., Spawn, S.A.. et. al. (2020). Protecting irrecoverable carbon in Earth's ecosystems. Nature Climate Change, 10(4). Retrieved from https://forestcarboncoalition.org/wp-content/uploads/2020/04/goldsteinetal2020wSI.pdf.

Table 7: Potential co-benefits and risks, relevant SDGs, and best practices to deliver co-benefits and minimize risks of five types of NbS measures. Green = benefit, Purple = risk, Grey = both a potential benefit or risk.[112]

	Biodiversity	Water	Soil	Air	Resilience	Livelihoods	Food security	Permanence	Relevant SDGs	Best practices to deliver co-benefits and minimize risks
Avoided deforestation									3,6,13,14,15	Control drivers of deforestation, prioritize primary forests, manage for permanence, establish protected areas, improve law enforcement, environmental governance, and land tenure; support community forest management
Afforestation / reforestation									3,6,13,15	Accelerate natural regrowth, reforest with native species, avoid afforestation of biologically diverse grasslands, avoid plantation monocultures in dry and sensitive areas, consider albedo in choice of species
Conservation and restoration of wetlands									3,6,11,13,14,15	Restore hydrological flows, accelerate natural regrowth, revegetate with native plants, reduce local stressors
Improved forest management									3,6,9,13,15	Improve schedule, intensity, and operations (thinning, selective logging, final cut, reduced impact logging, Pro Silva, fire mgmt, continuous cover mgmt)
Agriculture									1,2,3,6,7,8,12,13,14,15	1) Activities related to carbon sequestration: Promote planting of trees, cover crops, green manures, reduce tillage, longer rooted cultivars, optimal stocking rates and biochar on farms and ranches. Create market opportunities for tree products 2) Activities related to reductions in emissions: Improve livestock management (diets, species), use manure for fertilizer or energy, nutrient management, periodic draining of rice paddies

[112] Literature review including IPCC. (2019). Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Retrieved from https://www.ipcc.ch/srccl/.Dinerstein, E., Vynne, C., Sala, E., Joshi, A.R., Fernando, S., Lovejoy, T.E., Mayorga, J., Olson, D., Asner, G.P., Baillie, J.E. and Burgess, N.D., 2019. A global deal for nature: guiding principles, milestones, and targets. Science advances, 5(4). Retrieved from https://www.science.org/doi/pdf/10.1126/sciadv.aaw2869. Roe et al. (2021).

Climate Focus is an independent expert in international and national climate law, policies, project design and finance. We have been pioneering carbon markets ever since their inception. We aim to find a creative and unique solution for every single client, ranging from the development of policies to protect the rainforest to structuring greenhouse gas mitigation projects in the energy sector. Our advice is rooted in a profound knowledge of climate change policies, emission trading schemes and project development.

Climate Focus has offices in Amsterdam, Rotterdam, Washington DC, Berlin, and Bogotá. Our core team is complemented by a broad network of in-country and specialized partners.

CONTACT US

GLOBAL HEAD OFFICE
AMSTERDAM, THE NETHERLANDS
Climate Focus, B.V.
Van Diemenstraat 170
1013CP Amsterdam,
The Netherlands
T +31 20 262 10 30

ROTTERDAM, THE NETHERLANDS
Het Industriegebouw
Goudsesingel 52-214
3011 KD Rotterdam
The Netherlands
T +31 20 262 10 30

WASHINGTON, DC, USA
Climate Focus North America, Inc.
1701 Rhode Island Ave NW
Washington, DC 20036, USA
T +1 202 540 22 73

BERLIN, GERMANY
Climate Focus Berlin GmbH
Schwedter Str. 253
10119 Berlin, Germany
T +49 30 24637919

BOGOTÁ, COLOMBIA
Carrera 14 #89-48, 305
Bogotá, Colombia
T +57 1 322 73 54