Forest Mitigation: A Permanent Contribution to the Paris Agreement

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Executive Summary

The Paris Agreement set forth new global goals on mitigation. In order to meet such goals, emission reductions should exhibit permanence, which indicates the quality of a result lasting through time or where the net benefit of an action remains fixed for a long period. The opposite term, non-permanence, is used to represent situations where an achieved result is reversed or when an emission reduction is claimed due to actions undertaken, but in subsequent years such actions are reversed, resulting in the return of emissions.

Recent studies, as well as the Intergovernmental Panel on Climate Change (IPCC), in its recent Special Report on the impacts of global warming of 1.5°C, suggest that such goals cannot be met without a substantial contribution from forests. Halting conversion of forest into other land uses, ending forest degradation, and restoring peatlands would avoid accumulation in the atmosphere of around 30% of global anthropogenic CO_2 emissions. Additionally, by increasing CO_2 removals from the atmosphere, expanding forests is critical to reaching carbon balance by mid-century and limiting global warming to 1.5˚C or not exceeding 2˚C.

However, forest contributions have sometimes been ‘discounted’ by policy makers, climate negotiators, and groups that claim forest mitigation is not permanent and therefore should not be considered on par with emission reductions in, for example, the energy sector. This report suggests otherwise, for the following reasons:

1. Forests have been sequestering carbon for millions of years. Carbon stored in forests is about 1.3 times that in fossil fuel reserves. Furthermore, most forests currently are increasing their carbon stock (C stock) gain because of the impact of Nitrogen (N) deposition and atmospheric CO_2 increase as well as the increasing length of the “growing-season” in cold climates. Primary forests and peatlands have the largest long-term C stock—and therefore their protection must be a priority.
2. Terrestrial sinks (mostly forests) currently remove around 30% of human-caused CO_2 emissions and are the only carbon capture and storage approach proven to work at giga-ton scale and at costs well below current technological solutions such as direct air capture.
3. C pools are naturally adaptive to store C stocks toward a long-term average level at equilibrium[1] insofar as disturbances[2] do not progressively impact their capacity to store carbon. Consequently, despite inter-annual variability, only changes in the long-term average C stock have long-term/permanent impacts on atmospheric CO_2 concentrations.
4. To the atmosphere, CO_2 emissions from deforestation (i.e. a long-term net loss of carbon) are the same as CO_2 emissions from fossil fuels, $CO_{2LAND[long\text{-}term]} = CO_{2FUEL[fossil]}$. Avoiding emissions from deforestation and forest degradation is also no different than avoiding emissions from fossil fuels—the atmosphere sees the same thing.
5. To the extent there are risks of 'reversals' of a particular mitigation action, these risks exist in the forests sector as well as other sectors—for example, we have seen reversals in the energy sector as

[1] The long-term average C stock level at equilibrium in a land use and management system of practices is the average C stock stored in the land when net gains are equivalent to net losses across time. For ease of calculation, the time period considered can be 100 years so that the long-term C stock is calculated consistently with the way the GWPs are calculated for the GHG inventory; i.e. in function of their warming potential and their GHG’s resident time in the atmosphere averaged across a time period of 100 years. In this report the form “long-term C stock” is used to indicate the “average long-term C stock”.

[2] i.e. human and natural disturbances (e.g. planned harvesting and wildfires) that don’t permanently perturbate the forest capacity to recover C stocks (i.e. disturbances that don’t affect the long-term C stock). Consequently, deforestation and processes of forest degradation are not encompassed by this term.

countries move away from nuclear energy. All sectors have drivers of emissions that can be reversed. Therefore, it is critical that all mitigation actions are 'transformational'[3]. Transformational actions in forest land that reduce emissions also tend to increase removals[4]; such protected sinks further contribute to long-term increases in C stocks.

6. Reversals, across all sectors, are 'covered' through the inclusion of the source or land, and associated C pools, in nationally determined contributions (NDCs) due to the long-term responsibility of signatories to the Paris Agreement to take NDC and submit national GHG inventories[5] (NGHGIs). However, this is only the case if forests and land are fully integrated into accounting frameworks—for example, the substitution of bioenergy for fossil fuels, or wood products for other energy-intensive materials (e.g. cement, steel), requires linking forests and land to other sectors to ensure that accounted mitigation corresponds to what is actually "seen" by the atmosphere.
7. Accounting frameworks that operate on a shorter-term basis (e.g. crediting or trading mechanisms) have developed tools to manage risks of reversals from credited removals or emission reductions, such as insurance mechanisms (pooled buffer or reserve accounts), monitoring obligations beyond the accounting period, program design requirements (to ensure long term storage of C stocks), and liability provisions. The assignment of liability to national reporting and accounting of NDCs also promotes permanence, since the latter is a long-term commitment under the Paris Agreement.

Due to their dual role as both a source and sink in the global carbon budget, terrestrial C pools have been recognized as key actors to achieve stabilization of atmospheric concentration of GHG at a level that does not seriously harm human, socio-economic, and natural systems. Indeed, halting the conversion of forest land and peatlands and preserving and extending the current land sink are critical to avoiding global warming greater than 2 °C.

Currently, many countries with globally important forest have made commitments to reduce net emissions through submitted NDCs, that include the forest sector, under the Paris Agreement. Several donor governments have also pledged to support developing countries, in particular, with such efforts. In addition, many large multi-national companies have pledged to take deforestation out of their supply chains. While such transformational change is difficult to achieve, once in place it can also be difficult to reverse. In Europe[6], there is 30% more forest land since 1900 despite a significant increase in agriculture production. Reversing forest loss conserves biodiversity, protects watersheds and ecosystem services, regulates local and regional climate critical for sustained rural development, and provides livelihoods for forest-dependent communities. Science tells us that we cannot delay action if we are to avoid dangerous climate change—and forests can contribute, in permanent ways, to meeting such a goal.

This report therefore advocates for the full inclusion of forests in the nationally determined contributions of countries, and for taking actions to prevent long-term C stock losses in forest land and to enhance such long-term C stocks. Such full inclusion will not only preserve the environmental integrity of NDCs, it will also prevent accounting as mitigation the mere shift of emissions from sectors included in the NDC to the forest sector if excluded, or delinked, from the NDC.

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[3] Transformational changes remove the driver(s) of emissions such that emissions would not occur after the end of the period of activity (further discussed in Section 4).

[4] According to Le Quéré, C. et al (2018) - Global Carbon Budget. Earth Systems Science Data 10, 405-448 – there is a large residual sink on land that offset almost one third of anthropogenic emissions. This sink is mainly located in forest land (Schimel D. et al (2014) Effect of increasing CO_2 on the terrestrial carbon cycle, http://www.pnas.org/content/112/2/436.full, Keenan T.F. et al (2016) Recent pause in the growth rate of atmospheric CO_2 due to enhanced terrestrial carbon uptake, https://www.nature.com/articles/ncomms13428).

[5] Article 13 para 7 letter (a): "A national inventory report of anthropogenic emissions by sources and removals by sinks..."

[6] Fuchs, R. (2015). Gross changes in reconstructions of historic land cover/use for Europe between 1900 and 2010. Global Change Biology 21 (1)

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1. Preface

The climate system is determined by three components, the atmosphere, the land and the ocean. Atmospheric CO_2 is in a dynamic equilibrium among the atmosphere, the land (i.e. the terrestrial carbon pools), and the ocean. The mitigation framework established by the UNFCCC and its Paris Agreement focuses on the impacts of human action. This means that both the atmospheric CO_2 concentration and the carbon stored in terrestrial C pools should be counted, while oceanic CO_2 concentration may be excluded under the assumption that it is not directly impacted by human activities. Considering that the atmosphere and terrestrial C pools have a continuous and large[7] exchange of CO_2, the impact of a CO_2 molecule on global warming is function of its resident time in both components.

The term "non-permanence" is generally used to indicate the reversal of an achieved result, while its opposite, "permanence," indicates the quality of a result lasting through time. While the UNFCCC does not have an official definition of permanence in its reporting and accounting framework, references to the term have implicitly suggested two aspects related to the results of mitigation actions:

- Permanence of an emission (i.e. its resident time in the atmosphere) or a CO_2 removal (i.e. its resident time in the C pool), or an emission reduction;
- Permanence of the driver causing the emission and/or removal, i.e. the likelihood that after mitigation results have been accounted, the driver(s) counteracted by the mitigation action will be active again, reverting avoided CO_2 emissions or stored CO_2 removals to the atmosphere.

Non-permanence affects the integrity of any accounting mechanism for mitigation. This occurs when an accounted unit—i.e. one that does not actually correspond to either an avoided emission or an enhanced C stock because of a reversal—has not been cancelled or offset/replaced by another accounting unit.

Recent studies[8], as well as the Intergovernmental Panel on Climate Change (IPCC), in its recent Special Report on the impacts of global warming of 1.5°C, suggest that such goals cannot be met without a substantial contribution from forests. Halting conversion of forest into other land uses, ending forest degradation, and restoring peatlands would avoid accumulation in the atmosphere of around 30%[9] of global anthropogenic CO_2 emissions. Additionally, by increasing CO_2 removals from the atmosphere, expanding forests is critical to reaching carbon balance by mid-century and limiting global warming to 1.5˚C or not exceeding 2˚C[10].

This report focuses on CO_2 fluxes caused by human activities on lands and their deviation from business-as-usual levels and trends, where such deviations are accounted as results from the implementation of mitigation actions. When accounting for results and assessing their permanence, CO_2 fluxes associated with natural disturbances (see Box 1, page 7), as well as those associated with activities and disturbances that occurred before the onset of the mitigation actions (i.e. the legacy effect, see Box 2, page 7), must be zeroed out, since both are not directly associated with the mitigation actions.

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[7] The vegetation absorbs (gross photosynthesis) annually circa 123 Gt C and emit (respiration and wildfire) circa 118 Gt C https://www.fs.usda.gov/ccrc/topics/global-carbon)

[8] Rockström, J. et al (2017). A roadmap for rapid decarbonization. Science 355 (6331); Roe, S. et al (2017). How Improved Land Use Can Contribute to the 1.5°C Goal of the Paris Agreement (Working Paper) ClimateFocus.

[9] This figure has been calculated by summing up CO_2 emissions from gross deforestation, i.e. 2.8 Gt C yr^{-1}, estimated by Goodman R.C. and Herold M. (2014) Why Maintaining Tropical Forests Is Essential and Urgent for a Stable Climate - CGD Climate and Forest Paper Series #11 (figure 6.b www.cgdev.org/sites/default/files/CGD-Climate-Forest-Paper-Series-11-Goodman-Herold-Maintaining-Tropical-Forests.pdf), from forest degradation, i.e. 0.5 Gt C yr^{-1}, estimated from FAO FRA 2015 data (Federici, in elaboration), from peatland drainage, i.e. 0.5 Gt C yr^{-1}, estimated by Wetlands International (2009) in The Global Peatland CO_2 Picture (www.wetlands.org/publications/the-global-peatland-co2-picture/); from all other sectors as estimated by Le Quéré, C. et al (2018), Global Carbon Budget, (Earth Sys. Sci. Data 10, 405-448, www.globalcarbonproject.org).

[10] IPCC SR 1.5 (http://www.ipcc.ch/report/sr15/) and AR5 (http://www.ipcc.ch/report/ar5/wg3/).

All countries that ratify the Paris Agreement must submit nationally determined contributions (NDCs) that encompass significant emissions and removals, including from the land use sector. Furthermore, the Paris Agreement has established a universal obligation to regularly publish a national greenhouse gas inventory report (NGHGI), following IPCC guidance. Thus, all countries are expected to report time series of estimates of anthropogenic greenhouse gas (GHG) emissions and removals as included in the NDC. These provisions guarantee that any reversal is not only reported (at the time in which it occurs), but also that the country is held liable for such reversals through accounting for its NDC.

Carbon stored in forest land represents 55% of total C stock contained in terrestrial C pools[11] and exceeds by 30% the total carbon in fossil fuel reserves, and by more than 4 times the total amount of carbon that can be added to the atmospheric CO_2 concentration without exceeding the 2°C goal of the Paris Agreement (see Box 3, page 8). Forests currently remove from the atmosphere around one-quarter of anthropogenic CO_2 emissions, although increased afforestation may significantly increase this mitigation effect.

However, at present, human activities impact lands by using them for production of food and feed, biomaterials,[12] and biofuels at large scales,[13] resulting in deep alteration of resident C stocks[14] and their dynamics. An accurate estimate of anthropogenic CO_2 fluxes cannot overlook such changes. Current modeling suggests that pathways to limit temperature increases to 2°C likely require increasing use of biomaterials and bioenergy. However, if these are not sustainably produced, it would result in a significant displacement of emissions[15] from energy-related sources to lands, especially to forest land. For these reasons, it is critical to include forests in any accounting framework.

The Paris Agreement invites Parties to take action to conserve and enhance terrestrial sinks and reservoirs of GHG. Nevertheless, since the advent of the Kyoto Protocol, the liability of countries and local actors for emissions and removals from terrestrial C pools and their inclusion within market mechanisms have been contentious within UNFCCC negotiations. Critiques have pointed to

i. the concurrence of natural factors in determining emissions and removals from terrestrial C pools;
ii. the temporary nature of mitigation actions and consequently of their achieved results.

This report provides an analysis of the nature of CO_2 emissions and removals from managed terrestrial C pools, hereafter also referred as the land use sector[16], and of the nature of results achieved by mitigation actions in the land use sector. Although the analysis focuses on the permanence of climate results achieved through mitigation activities that affect forest land, i.e. activities for reducing C stock losses and enhancing C stocks of forests, the content of this report may be applied to all other terrestrial ecosystems (although for peatlands, see Box 4 on page 8, such general considerations may not apply).

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[11] IPCC Third Assessment Report: The Carbon Cycle and Atmospheric Carbon Dioxide; at https://www.ipcc.ch/ipccreports/tar/wg1/pdf/TAR-03.PDF (Table 3.2, assuming that 10% of savannas and shrublands are classified within forest land)

[12] According with data reported in FAOSTAT database (http://www.fao.org/faostat/en/#data/FO), around 1 Pg C yr^{-1} of wood has been harvested in 2016, that where not serving from a sustainable management of forest may determine a net decrease in the long-term C stock of forest land and consequently a net accumulation of carbon into the atmosphere.

[13] Currently, human activities are consuming around 40% of the global net primary production (www.nature.com/nature/journal/v429/n6994/pdf/nature02619.pdf); the forecasted increase of human population and of its consumption of biomaterials, including biofuels, and the contemporary decrease in primary production due to deforestation and land degradation, including forest degradation, and negative impacts of climate change may likely increase such quota over 50% by 2030.

[14] Deforestation only has been estimated to have transferred around 150 Pg C (1870-2016) just in the period 1870-2016.

[15] Where CO_2 emissions from bioenergy are not accounted for in the land use sector, bioenergy cannot be assumed to be carbon neutral since the production and use of biofuels may determine a decrease in the long-term C stock of land (see figure in section 3). For instance, according to global data on fuelwood production (http://www.fao.org/faostat/en/#data/FO), almost 2 Gt CO_2 yr^{-1} are currently emitted by its use although not accounted for since deemed to be at equilibrium with atmospheric CO_2 concentration (i.e. the CO_2 emissions will be taken back by the subsequent regrowth of forest)

[16] Sector of a NGHGI

Box 1. Natural Disturbances

The annual GHG net flux[17] of a managed land is the result of multiple causes/drivers that can be aggregated within three groups: (a) those directly attributed to human activities (e.g. harvesting, planting, fires); (b) those indirectly attributed to human activities (mainly N and CO_2 fertilization, climate change); and (c) natural, including natural disturbances (mainly fires, drought, pests).

Although it is possible to list these causes/drivers of emissions and removals, it is not possible to separate their contribution to the GHG net flux in each specific land and occurrence. For example, it is difficult, if not impossible, to separate out the causes of GHG emissions and subsequent removals for every forest fire. Fires are part of the natural regeneration cycle of forest ecosystems. However, they may also be the intentional or unintentional consequences of human activities, and their frequency and intensity are directly impacted by climate change (an indirect consequence of human activities). Consequently, the total emissions and removals associated with forest fires is the result of a range of causes— anthropogenic, direct and indirect, and natural— that influence each other. Consider, for instance, a country in which all forest fires are anthropogenic, and the number of fires is the same in three consecutive years, but where summer weather conditions vary, so the first year is wet and mild, the second dry and warm, and the third dry, hot, and windy. This variability in weather condition is natural but also, because of climate change, indirectly-human induced. In terms of the impacts of the forest fires, GHG fluxes associated with fires occurring in the first year will be an order of magnitude smaller than those associated with fires occurring in the second year and much smaller than those in the third year. So, although all fires are anthropogenic, and the frequency of occurrence is the same, the results are different because the impact of natural variability *and* because of human-induced climate change. Nevertheless, it is possible to statistically identify the impact of natural disturbances from human causes, for example, when the net GHG flux exceeds (i.e. is a statistical outlier) the typical range of observed variability over a period of years, the fraction of GHG flux that exceeds such typical range can be estimated as the direct consequence of natural disturbances.

Box 2. Legacy of disturbances in C stock dynamic

C stocks in C pools tend naturally towards long-term average level at equilibrium[18] where C stock gains are equivalent to C stock losses. This means that, when in one year a disturbance (natural or human-induced) alters the equilibrium, the C pool reacts in subsequent years to restore the equilibrium. Consequently, in the year of occurrence, a disturbance can determine either: (a) a net carbon accumulation, i.e. harvesting/fires often result in immediate accumulation of dead organic matter (which decays in subsequent years), or (b) a net loss of C stocks, i.e. harvesting/fires results in immediate loss of biomass pools (although the C stock returns in the following years). In summary:

- A CO_2 emission associated with a C stock loss can revert from the atmosphere because of the subsequent vegetation regrowth;
- A CO_2 removal associated with a C stock gain may revert to the atmosphere because of a subsequent disturbance (human or natural).

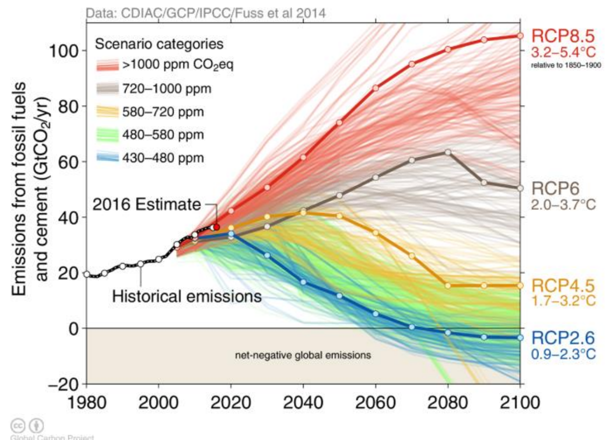
Consequently, “net emission reductions” as well as “net removal enhancements” may over-account what is actually seen by the atmosphere across a time period longer than the time period of accounting for mitigation results. Similarly, “net emission increases” as well as “net removal decreases” may be over-accounted if the legacy effect is not considered.

[17] and the associated long-term C stock
[18] Although human impacts (i.e. N deposition, CO_2 atmospheric concentration, increasing length of growing-season, other climate change impacts) are altering its magnitude, the “equilibrium level” remains a valid law in the ecology of C pools.

Box 3. Representative Concentration Pathways

Representative Concentration Pathways (RCPs) are GHG concentration (not emissions) trajectories adopted by the IPCC for its Fifth Assessment report (AR5)[19]. They describe four climate futures, all of which are considered possible depending on GHG emissions in the years to come. The RCPs (RCP2.6, RCP4.5, RCP6.0, and RCP8.5) are named after a possible range of radiative forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 W/m^2, respectively).

AR5 global warming increase (°C) projections		
time period	2046-2065	2081-2100
Scenario	Mean and likely range	
RCP2.6	1.0 (0.4 to 1.6)	1.0 (0.3 to 1.7)
RCP4.5	1.4 (0.9 to 2.0)	1.8 (1.1 to 2.6)
RCP6.0	1.3 (0.8 to 1.8)	2.2 (1.4 to 3.1)
RCP8.5	2.0 (1.4 to 2.6)	3.7 (2.6 to 4.8)



Box 4. Peatlands

Peatlands are a part of the terrestrial C pool. However, unlike forests that (if left undisturbed) have a long-term C stock, the carbon stored in peatlands does not tend toward an equilibrium. Peat can sequester an unlimited amount of carbon if pedoclimatic conditions (i.e. soil temperature, water, aeration) allow.

Without human intervention i.e. drainage, most of the carbon stored in peatlands would never react with the atmosphere. Consequently, peat can be considered a fossil C stock that would not be emitted to the atmosphere without human action, similar to other fossil fuels.

Similarly, if drivers of drainage (e.g. soil cultivation) have been permanently removed—such that peat cannot be disturbed in the future—this action (to avoid peat emissions) is no different, and no less permanent, than an avoided fossil fuel emission associated with a transformational change.

[19] http://www.ipcc.ch/report/ar5/index.shtml

2. The role of terrestrial C pools for mitigation of climate change

Terrestrial C pools contain the stocks of living organic matter (biomass) and dead organic matter (dead wood, litter, soil organic carbon, and harvested wood products) associated with vegetation. Such pools remove CO_2 from the atmosphere through photosynthesis and emit CO_2, CH_4 and N_2O from redox[20] of organic matter associated with continuous processes such as decay[21] or sudden events such as wildfires.

Terrestrial C pools store around 1.9 Eg[22] C (~1.4 in soils and ~0.5 in phytomass)[23], mainly in forests[24] (1.1 Eg C), and peatlands[25] (0.6 Eg C). The total carbon stored in forests alone is 1.3 times larger than the carbon stored in fossil fuels reserves (~0.8 Eg C)[26], and more than the carbon already added to the atmosphere as a consequence of human activities since 1870 (~0.6 Eg C)[27]. This stored quantity also exceeds the quota of emissions that can be added to the atmosphere in order to keep the increase in average global temperature below 2 °C (0.2 Eg C)[27].

Until 1950, CO_2 emissions from terrestrial C pools were the main flux of CO_2 emissions caused by human activities. Around one-quarter of total anthropogenic CO_2 emissions since 1870 have been sourced from terrestrial C pools[27]. In recent years, largely due to the growth of fossil fuel emissions, net land use change (largely deforestation) has declined to around 10%[28] of total global anthropogenic CO_2 emissions—but more importantly, the land use sector (largely forests) remove from the atmosphere 30% of total anthropogenic CO_2 emissions[29]. If only anthropogenic emissions (and not removals) are considered, gross deforestation, forest degradation, and peatlands drainage would together comprise around one quarter of global total CO_2 emissions[30].

Due to their dual role as both a source and sink in the global carbon budget, terrestrial C pools have been recognized as key to achieve stabilization of atmospheric concentration of GHG at a level that does not seriously harm human, socio-economic, and natural systems. In addition, most forests currently are increasing their carbon stock (C stock) gain because of the impact[31] of Nitrogen (N) deposition and

[20] Redox reactions include all chemical reactions that involve the transfer of electrons between chemical species. The chemical species from which the electron is lost is said to have been oxidized (gain of oxygen), while the chemical species to which the electron is added is said to have been reduced (loss of oxygen). Oxidation is generally associated with oxygen availability (oxic conditions) while reduction with anoxic conditions.

[21] Decay processes determine a chain of organic compounds with a continuous loss of weight, also caused by CO_2 emissions, from biomass to dead wood and litter to soil organic matter and its subsequent respiration to CO_2 emissions.

[22] An Exagram corresponds to 10^{18} grams or a thousand Gt, e.g. 1.9 Eg C corresponds to 1,900 GtC (or ~7,000 Gt CO_2).

[23] Scharlemann, J. et al (2014). Global soil carbon: understanding and managing the largest terrestrial C pool, Carbon Management (5:1, 81-91, DOI: 10.4155/cmt.13.77) estimate a global total C stock stored in phytomass and soil of circa 1912 Pg C of which around 60% (IPCC Special Report on LULUCF) is stored in forest land, while McGlade, C. and Ekins, P. (2015) [The geographical distribution of fossil fuels unused when limiting global warming to 2 °C. Nature, 517 (7533) pp. 187-190] estimate fossil fuels reserves at 2,900 Gt CO_2, equivalent to almost 75% of the phytomass and soil C stocks, and the fossil fuels resources at 11,000 Gt CO_2 equivalent to almost three times the phytomass and soil C stocks.

[24] 2000 IPCC special report on Land Use, Land-Use Change and Forestry

[25] Note that some forests occur on peatlands

[26] McGlade, C. and Ekins, P. (2015). The geographical distribution of fossil fuels unused when limiting global warming to 2 °C. Nature, 517 (7533) pp. 187-190.

[27] Le Quéré, C. et al (2018). Global Carbon Budget. *Earth Systems Science Data 10*, 405-448 - http://www.globalcarbonproject.org/

[28] Net deforestation from Le Quéré, C. et al (2018). Global Carbon Budget. *Earth Systems Science Data 10*, 405-448 - http://www.globalcarbonproject.org//

[29] Le Quéré, C. et al (2018). Global Carbon Budget. *Earth Systems Science Data 10*, 405-448- http://www.globalcarbonproject.org/

[30] This figure has been calculated by summing up CO_2 emissions from gross deforestation, i.e. 2.8 Gt C yr^{-1}, estimated by Goodman R.C. and Herold M. (2014), Why Maintaining Tropical Forests Is Essential and Urgent for a Stable Climate, CGD Climate and Forest Paper Series #11 (figure 6.b at www.cgdev.org/sites/default/files/CGD-Climate-Forest-Paper-Series-11-Goodman-Herold-Maintaining-Tropical-Forests.pdf, from forest degradation, i.e. 0.5 Gt C yr^{-1}, estimated from FAO FRA 2015 data (Federici, in elaboration), from peatland drainage, i.e. 0.5 Gt C yr^{-1}, estimated by Wetlands International (2009) in The Global Peatland CO_2 Picture (www.wetlands.org/publications/the-global-peatland-co2-picture); from all other sectors as estimated by Le Quéré, C. et al (2018), Global Carbon Budget, (Earth Systems Science Data 10, 405-448, www.globalcarbonproject.org).

[31] Federici, S, Grassi, G, Harris, N, Lee, D, Neeff, T, Penman, J, Sanz, MJ, Wolosin, M (2017). GHG Fluxes from Forests: An assessment of national GHG estimates and independent research in the context of the Paris Agreement.

atmospheric CO_2 concentration increase as well as the increasing length of the "growing-season" in cold climates. Primary forests and peatlands, in particular, have the largest long-term C stock. Indeed, halting the conversion of forest land and peatlands in agricultural or other uses of land and preserving the current land sink[32] would avoid more than one-third of global anthropogenic emissions[33]. In other words, failing to protect and sustainably manage forests and peatlands will accelerate by almost one-third the current pace of carbon accumulation into the atmosphere.

Additionally, enhancing the current sink, especially through afforestation, would further increase the mitigation potential of terrestrial C pools. The IPCC, in its latest assessment report[34] and its recent special report on global warming of 1,5 degrees[35], considers the role of terrestrial C pools, particularly large-scale afforestation, among the most efficient mitigation options to avoiding global warming greater than 1.5-2°C[36]. Such mitigation potential is reflected in NDCs under the Paris Agreement, where the management of terrestrial C pools, especially forests, constitutes one-quarter of the collective commitment[37]. A failure to achieve this mitigation would double the gap[38] between current NDCs and a global net emission benchmark consistent with a pathway[39] to keep global warming below 2°C.

Further, forests are the habitat of around 80% of terrestrial biodiversity and provide indispensable and irreplaceable services beyond carbon sequestration and storage. Forests regulate local climate, enhance air quality, prevent soil erosion, improve soil fertility, and increase water availability and quality—leading to more reliable food production and advancing other societal goals.

Summary: The role of terrestrial C pools for mitigation of climate change

- Forest land stores 60% of the total C stock contained in terrestrial C pools, 40% more carbon than that contained in fossil fuels deposits, and almost five times more carbon than can be added to the atmosphere without exceeding the 2 °C goal.
- The *net* CO_2 balance of land use change (largely deforestation) is currently responsible for around 10% of global anthropogenic CO_2 emissions; while *gross* deforestation, forest degradation and peatlands drainage are collectively responsible for around one quarter of the global total.
- Forests remove almost one-third of total emissions due to forest management, including natural forest expansion, and the indirect effects of human activities. New afforestation activities could significantly increase this mitigation effect.
- Failing to protect and expand the carbon stored in forests will make it impossible to keep global average temperature increase below 2 °C.

[32] Including by avoiding forest degradation
[33] Considering that anthropogenic CO_2 emissions from fossil fuels and cement are 34.3 Gt CO_2 yr^{-1} and the net C stock loss from land is 4.9 Gt CO_2 yr^{-1}, halting deforestation, forest degradation and peat drainage will zero out the land component and preserve the current land sink of 11.2 Gt CO_2 yr^{-1} which corresponds to about 1/3 of anthropogenic emissions from fossil fuels and cement; see www.globalcarbonproject.org/carbonbudget/17
[34] https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_summary-for-policymakers.pdf
[35] IPCC special report on the impacts of global warming of 1.5 °C (http://www.ipcc.ch/report/sr15/)
[36] According to the mitigation scenarios and associated RCP2.6, failure in achieving net emissions at scale by 2050 will lock societies in a high temperature future.
[37] Grassi G. et al (2017). The key role of forests in meeting climate targets requires science for credible mitigation. Nature Climate Change, doi:10.1038/nclimate3227
[38] http://climateactiontracker.org/global/173/CAT-Emissions-Gaps.html (~14.5 Gt CO_2eq yr^{-1})
[39] RCP2.6

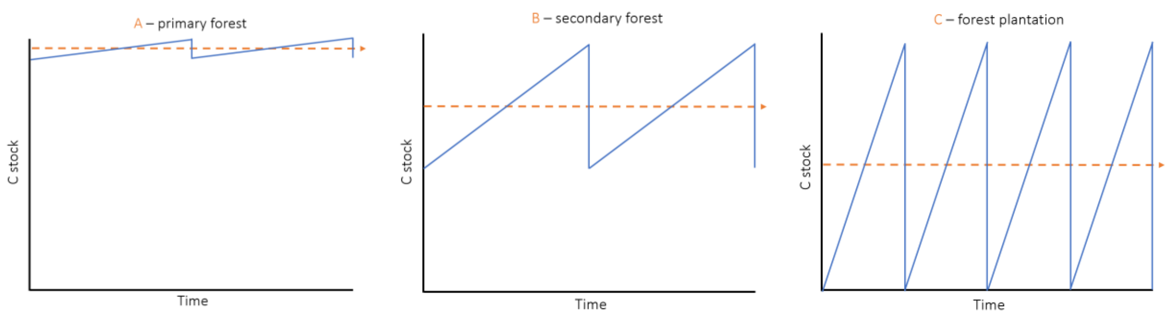
3. The nature of CO_2 emissions and removals from the land use sector

Carbon contained in fossil fuels is stored in geological deposits confined from the atmosphere. Because of human activities that extract and oxidize it, fossil carbon is added to the atmosphere, or more precisely to the atmosphere-land-ocean system[40]. These emissions, and their avoidance, are considered permanent, because emitted fossil carbon does not revert to the geological deposits during human time scales.

The organic carbon contained in terrestrial C pools is subject to natural and human-induced processes of: sequestration from the atmosphere; accumulation in the C pools; decay to the atmosphere[41]. An equilibrium state of C stock stored in each terrestrial C pool can be quantified as a long-term average. The long-term C stock takes into consideration the resident time of carbon within the C pools (see Box 5 below) and is determined by the ecological conditions, the system of management practices (i.e. land use) and the associated regime of natural and anthropogenic disturbances. A change in any of these factors can result in a change in the long-term C stock.

The long-term C stock of a land area represents what the atmosphere sees as the land's overall contribution to the atmospheric CO_2 concentration, although annually CO_2 emissions may not be equivalent to CO_2 removals. Consequently, any net change in the long-term C stock caused by a change in activities (e.g. a change in land use or management) results in a total permanent net impact on the atmosphere, as illustrated in Box 5.

Box 5. Long-term C stock of various forest types



In the three graphs, the blue lines represent the C stock level across time, with C stock losses followed by equivalent C stock gains. Although in all three forests types there are CO_2 emissions and removals across time, it is possible to estimate a long-term net impact on the atmospheric CO_2 concentration for each of them i.e. their long-term C stock (the dotted lines). While the three forest types have almost equivalent peaks of C stock, the different resident time of carbon in C pools makes each forest's contribution to the atmospheric CO_2 concentration significantly different. As illustrated in the graphs, compared to primary forests, the long-term C stock of secondary forests is 25% less and of forest plantations is 50% less.

Consequently, the conversion of a primary forest to a secondary forest or to a forest plantation results in a permanent loss of C stock and therefore a permanent increase in the atmospheric CO_2 concentration. Alternately, the conversion of a forest plantation to a secondary forest or of a non-forest land to a forest land is a permanent C stock gain and therefore a permanent decrease in the atmospheric CO_2 concentration.

[40] According to the globacarbonproject.org, 26% of CO_2 emitted to the atmosphere since 1870 has been absorbed by oceans, 31% has been absorbed by land, and the remaining 44% has accumulated in the atmosphere.
[41] Peatlands are an exception, since they act as an almost unlimited carbon sink (Box 4).

The reporting instrument under the Paris Agreement, the national GHG inventory (NGHGI), is a permanent obligation that requires all countries to submit regular (at least every two years) time series of estimates of annual anthropogenic CO_2 emissions and removals. All annual CO_2 emissions and removals are reported within NGHGIs, and their net impact on the atmosphere should be estimated. Within the cultural cycle, CO_2 emissions in one year may be offset by CO_2 removals in subsequent years, and vice versa. Consequently, over time, NGHGIs capture the net permanent effect of changes in the long-term C stock as time series of annual emissions and removals. In other words, the sum of annual CO_2 fluxes across the conversion period[42] should reflect the total net change in the long-term C stock[43] and therefore the net impact on atmospheric CO_2 concentration (see Box 6 on next page).

As noted in Box 4 (page 8), peatlands do not have a long-term C stock level, since they tend to accumulate carbon indefinitely if the pedoclimatic conditions allow. Human activities, however, may turn the indefinite CO_2 sink into a CO_2 source, and cause a permanent net emission, since stored CO_2 is not emitted in absence of a human intervention, and only if a transformational change occurs, for example when rewetting occurs a permanent net removal CO_2 is accounted.

Summary: Nature of CO_2 emissions and removals from the land use sector

- CO_2 emissions from fossil fuels are understood as a permanent addition to the atmosphere, although half of these emissions are annually removed by the land and ocean.
- The long-term C stock of the land represents the permanent impact of land on atmospheric CO_2 concentration.
- Changes in the long-term C stock from land use are long-term permanent CO_2 additions to, or subtractions from, the atmosphere and therefore equivalent to net changes in CO_2 emissions from fossil fuels.
- Changes in the long-term C stock of any land are reported, when they occur, within a NGHGI as annual CO_2 emissions and removals, whose sum across a time series (covering the full conversion period) quantifies the permanent net flux.

[42] i.e. the time need to C stocks to move from the long-term equilibrium of the previous use and/or management system to the new one.
[43]Indeed, counting the time series of annual losses and gains of C stocks in a conversion from e.g. a primary forest to a secondary forest ultimately counts for the net difference between the two long-term C stock (see Box 5).

Box 6. Impact on atmospheric CO_2 of a forest management change, from clearcut to selective logging

In any year of the time series of annual estimates reported in a GHG inventory, the sum of CO_2 emissions and removals occurred in the year reflects the impact on atmospheric CO_2 concentration *in that year* from a management change. The total net impact of the management change, however, would be the change in the sum of annual fluxes across complete management cycles. In the figure below, for example, it would mean comparing the time series of annual CO_2 emissions and removals during the management cycles of clear-cut harvesting (time a.) to the annual CO_2 emissions and removals during management cycles of selective logging (time b.). The comparison of total net CO_2 emission/removal across the management cycles gives the long-term C stock increase (as demonstrated in Figure B) caused by the the conversion from clearcut to the selective logging system.

Figure A: Annual C stock changes (CO_2 emissions and removals) reported in the NGHGI
Note: Green bars represent forest growth (negative value: CO_2 removals); Red bars represent forest harvesting (positive value: CO_2 emissions)

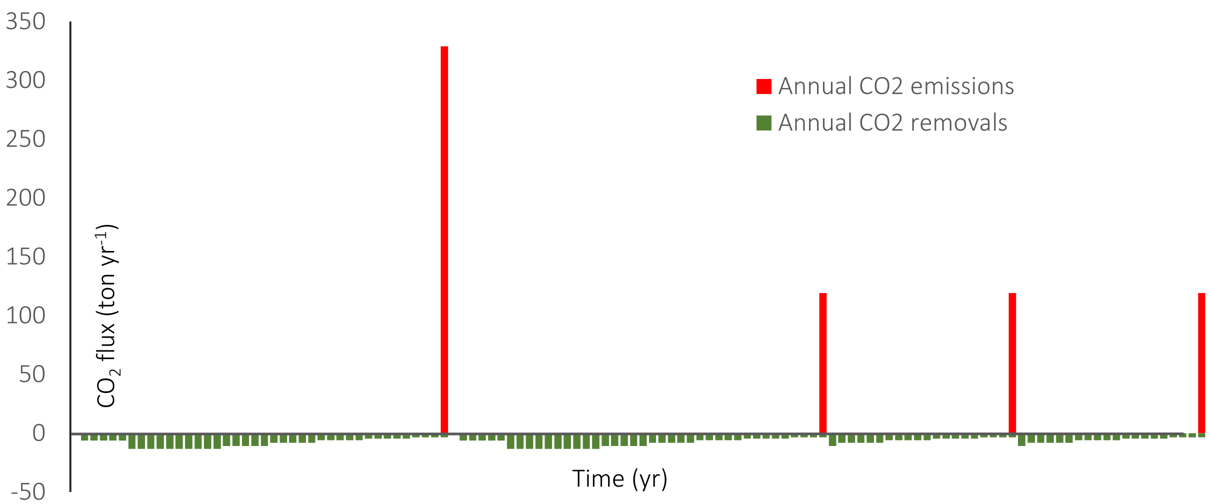
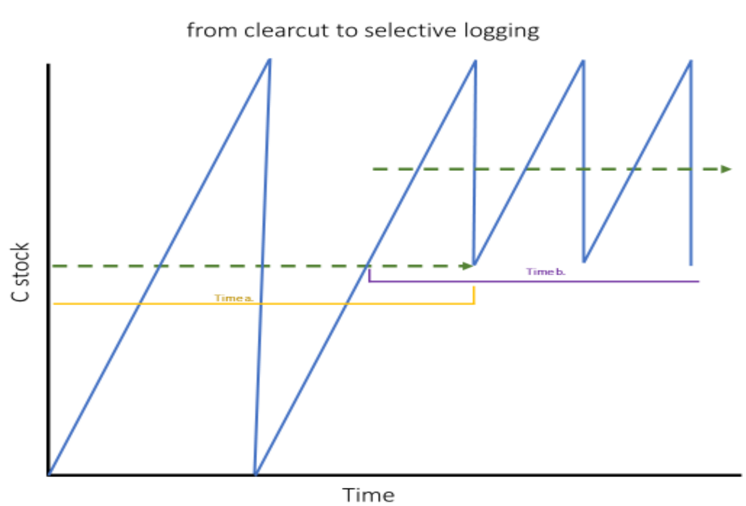


Figure B: C stocks dynamic in forest land
Note: Blue lines represent current C stocks; Green lines represent long-term C stocks



4. Drivers of CO_2 emissions and removals in the land use sector

As noted in the Preface, under the UNFCCC reporting and accounting framework the term "permanence" refers to two aspects of the results of mitigation actions[44]:

A. Permanence of an emission, i.e. its resident time within the atmosphere, or a removal, i.e. its resident time in the C pools;

B. Permanence of the driver causing the emission and/or removal, i.e. the likelihood that after mitigation results have been accounted for the driver(s) that was counteracted by the mitigation action will be active again, resulting in the accounted emission reduction or removal to be emitted.

Regarding A, the previous section of this report concluded that because both CO_2 emissions and removals from terrestrial C pools may be part of a unique activity, e.g. forest harvesting and subsequent forest regrowth, the CO_2 resident time of an emission (into the atmosphere) or a removal (into the C pools) in the land use sector may be shorter than that of an emission from a fossil fuel (into the atmosphere). By contrast, the long-term C stock establishes full comparability among CO_2 fluxes generated by the land use sector and those from other sectors of the NGHGI.

This section focuses on the second aspect of permanence: the drivers of CO_2 emissions and removals. Drivers determine whether an achieved result, i.e. an avoided emission or enhanced C stock, may be reversed in the future. In case a mitigation action does not remove the drivers permanently, it may again cause CO_2 emissions after the action ends. For example, a hectare of forest saved this year from conversion because of specific enforcement activities may be converted in a following year if such enforcement is halted; similarly, an amount of fossil fuel not used in a particular year because of an incentive related to public transport may be used in private cars and emitted in a following year if the incentive is not renewed (see box 7 on the temporary effects of non-transformational changes).

Consequently, within a project- or program-based accounting framework, only projects or programs[45] that implement transformational changes may ensure permanence of achieved results, because they remove the driver(s) of emissions such that emissions would not occur after the end of the period of activity. For instance, shifting to a vegetarian diet would permanently reduce one's carbon footprint[46], or the establishment of a forested national park would preserve all achieved C stock gains and would avoid further permanent C stock loss. Similarly, phasing out internal combustion engines and replacing them with electric engines coupled with the use of renewable energy can permanently reduce the carbon footprint of the transportation sector.

Within a NGHGI-based accounting framework as the Paris Agreement, no emissions will be unaccounted after the end of mitigation actions since NDCs and the underlying NGHGI are a permanent obligation of each country. Consequently, the permanence (or non-permanence) of drivers does not impact the accounted quantities over time; indeed, any emission and removal that occurs after the end of the mitigation action will be reported and accounted.

Considering first fossil fuels emissions, the only driver is human activity. Human activities cause fossil fuel redox and associated GHG emissions, such that an increase[47] in activities drives a rise of GHG emissions (although additional emissions may be avoided through energy efficiency and renewable energy).

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[44] i.e. reduced emission or enhanced removal

[45] Without distinction among sectors of the NGHGI targeted by the project

[46] Even if the person subsequently shifts to a meat-based diet, the emissions saved during the "vegetarian phases" will not be emitted anymore.

[47] Associated with human population growth and with intensification of activities

Consequently, any variation in the amount and trend of GHG emissions from fossil fuels occurring in any year across a time series is an indicator of a change, occurring in that year, of the unique driver. While replacing fossil fuels with renewable power may be considered as transformational change, other instruments used as incentives to reducing using fossil fuels, or fiscal measures to make their use more onerous, may exhaust their impact once they are halted or they may be neutralized by the market, with a consequent reversion to fossil fuel use and associated GHG emissions.

In the land use sector, the annual C stock balance of a managed land is determined by the concurrent impacts of human activities and natural variables[48]. The impact of natural variables may materialize as disturbances[49]. However, while human activities result in a permanent net change in the long-term C stock of a land, a natural disturbance only causes temporary C stock losses. Indeed, after a disturbance, forest regrowth accumulates C stocks to their pre-disturbance levels (see figure in Section 3 box) particularly in primary forests where C stocks losses are exclusively caused by natural disturbances. Therefore, although natural disturbances may impact the annual CO_2 flux of an area of land, their occurrence does not impact the long-term net flux, since associated emissions and removals balance out across time. However, where external factors intervene, for instance the change in the frequency of natural disturbances due to climate change itself[50], C stock losses may not be followed by equivalent stock gains—this is not the impact of natural disturbances but rather an indirect human induced impact.

Drivers of CO_2 emissions and removals in the land use sector have another significant characteristic: they impact, non-linearly, CO_2 emissions and removals in the year of occurrence but also in subsequent time periods even if the driver is no longer occurring. Indeed, both human activities and disturbances result in processes of carbon accumulation—e.g. forest regrowth after harvesting or decay—that remain active well beyond the year in which the activity or disturbance has occurred. This characteristic is generally referred to as a 'legacy effect' (see Box 2). This means that the positive impact of a mitigation action usually lasts, or sometimes even increases, in years subsequent to its implementation; for example, the revegetation or afforestation of degraded land may continue to accumulate carbon for centuries after the initial establishment.

Transformational changes in the land use sector are usually associated with legislation or policies, e.g. the establishment of a national park or securing forest land tenure to local communities and binding its use to forest. Other actions may also result in permanent changes to drivers, such as the establishment of rules and guidance for the sustainable management of degraded land.

Summary: Drivers of CO_2 emissions and removals, including in the land use sector

- Without distinction among sectors (applies to both fossil fuels and land use):

  Human activities that drive emissions may return as a mitigation action ends or loses its effectiveness; transformational changes address drivers far beyond the end of the initial mitigation action;

  Any reversal of accounted avoided emissions/enhanced C stocks will be eventually reported within repeated NGHGIs; due to their long-time horizon, NGHGIs quantify the impact of recurrent drivers that reverse previously accounted quantities.

- In the land use sector, addressing drivers of emissions often also results in additional CO_2 removals; a failure to recognize such CO_2 removals would bias the accounted results.

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[48] Most relevant are the temperature and humidity regimes.

[49] E.g. forest fires were an important ecological factor also before the appearance of the human beings (natural disturbance). Noting however, that from the appearance of humans, forest fires are also a consequence, direct and indirect, of human activities (anthropogenic disturbance).

[50] https://www.carbonbrief.org/factcheck-how-global-warming-has-increased-us-wildfires

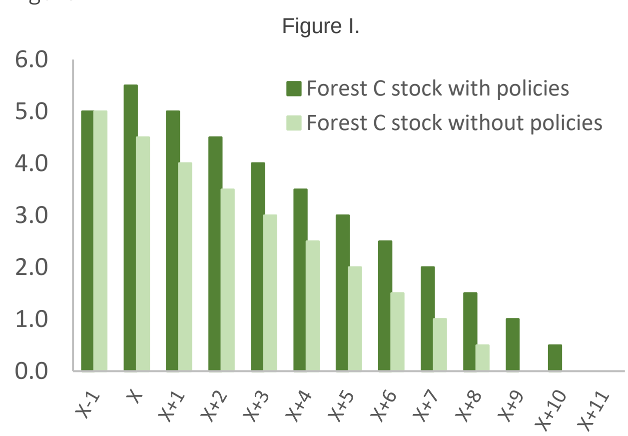
Box 7. Temporary effect of non-transformational changes

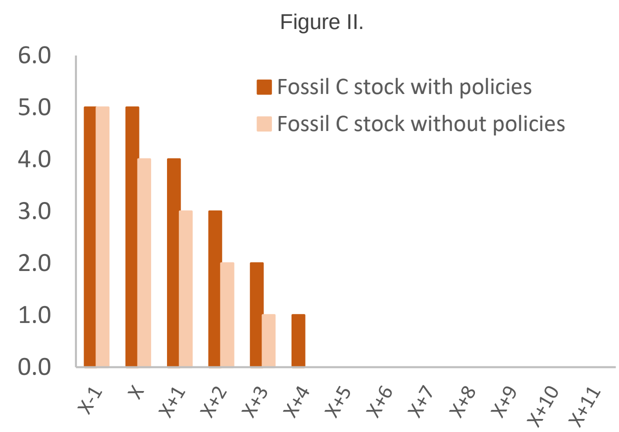
Both the carbon stored in terrestrial C pools and the carbon stored in geological deposits (coal, gas and crude oil) are finite, so policies that only have a temporary effect on the rate of consumption of terrestrial C stocks or of fossil C stocks just delay emissions rather than permanently reduce/avoid the release of such stocks.

Let's consider a simplified system where there is a single land covered by a forest and a single geological deposit of fossil fuel (e.g. crude oil). The rate of consumption of both C stocks is equal to -1 kt C yr^{-1}; further, forest regrowth sequesters back half kt per year i.e. +0.5 kt C yr^{-1}. Let's now assume that at the beginning of a year X both stocks have same C content, e.g. 5 kt C, then because of 2 temporary policies (policy A in the forest sector and policy B in the energy sector) the consumption of the forest C stock as well as of the fossil fuel C stock is zeroed out (i.e. in year X the harvest of wood is 0 kt C and the spilling of crude oil is 0 kt C); consequently at the start at the end of that year X the forest C stock and fossil C stock are both equal to 5 kt C.

From year X+1 onward the rate of consumption is again 1 kt C yr^{-1} for both C stocks since both policies A and B are expired or have "reversed". Consequently, as illustrated in figure A, in the year X+1 the fossil C stock is 4 kt C (5 kt C – 1 kt C) while the forest C stock is 4.5 kt C (5 kt C – 1 kt C + 0.5 kt C), in the year X+2 the fossil C stock is 3 kt C (4 kt C – 1 kt C) while the forest C stock is 4 kt C (4.5 kt C – 1 kt C + 0.5 kt C), and in the year X+5 the fossil C stock is 0 kt C (1 kt C – 1 kt C), while the forest C stock is 3 kt C (3.5 kt C – 1 kt C + 0.5 kt C).

Figure A:

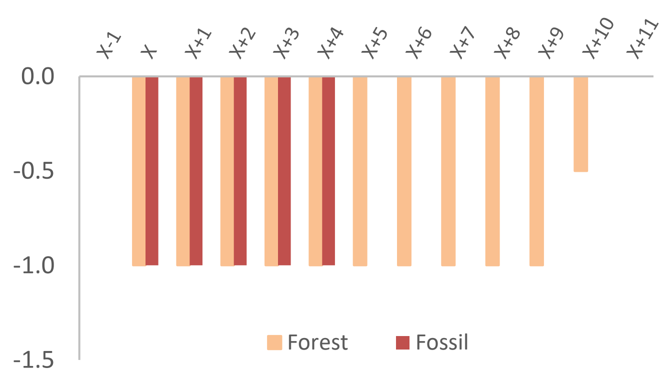




Figures I. (forest) and II. (fossil) show both C stock dynamics, that occurred under the implementation of the related policy and that that would have occurred in absence of the policy. For both C stocks i.e. forest and fossil- policies have had just a temporary impact. Indeed, both emissions, i.e. fossil-fuel-related and organic-matter-related, have just been delayed by 1 year only: without the policies the fossil C stock would have been completely used up in the year X-4 and in that year the forest C stock would have achieved a level of 3.5 kt C.

Figure B:

In the figure on the right, the cumulated net impact on the atmospheric CO_2 concentration of the policies is reported. Note that the impact of the forest-related policy lasts longer (i.e. until year X+10) than that of the fossil-related policy (i.e. until year X+4 only).



5. Accounting of mitigation actions in the land use sector

The goal of mitigation actions is to avoid further increases of atmospheric GHG concentration or to reduce it. Mitigation results (AQ_{MR})[51] are therefore accounted as the achieved deviation from the GHG fluxes that would occur in absence of the action i.e. the counterfactual value[52]. Mitigation results (AQ_{MR}) are thus accounted by subtracting expected GHG fluxes ($GHG_{EXPECTED}$) from actual GHG fluxes (GHG_{ACTUAL}): $AQ_{MR} = GHG_{ACTUAL} - GHG_{EXPECTED}$.

As discussed in the previous section, when accounting for mitigation results in the land use sector, legacy effects of activities and disturbances that occurred on the land before the onset of the mitigation action, as well as the impact of ongoing natural disturbances, may contribute to annual GHG fluxes—i.e. annual GHG fluxes may include emissions and/or removals not associated with the specific mitigation actions taken. Because fluxes average out across long time periods (e.g. the time needed to forest biomass to regrow after a disturbance, or the time period for dead organic matter originating from a disturbance to fully decay), the results accounted across a limited time period may not fully reflect what is actually seen by the atmosphere in the long run as a consequence of the mitigation action. For such reason, when accounting for results of mitigation actions in the land use sector, emissions and removals due to the legacy of previous human activities, as well as those associated with natural disturbances, should be separated from the GHG balance of each land area. In practice, what is needed is to identify and measure the signal (the mitigation results from actions taken) separate from the noise (the legacy effects and natural disturbances).

To manage legacy effects, two conditions should be satisfied in the accounting:

A. legacy emissions/removals from activities and disturbances that occurred in the land before the onset of the mitigation action should be accounted as zero (while ensuring no anthropogenic fluxes are excluded);

B. mitigation results are accounted across a time period equal to the period needed to exhaust the legacy effect caused by the mitigation action.

Such conditions are satisfied by the following two approaches that can be implemented to deal with the legacy effect on accounting for mitigation results:

Approach I (used under the UNFCCC, or Convention): Compare NGHGI estimates of various years (e.g. base year vs current years), where:

- *to comply with A*: the legacy emissions and removals associated with activities and disturbances that occurred on the entire national land territory before the onset of the mitigation actions are implicitly assumed to be equivalent to what would have occurred during the accounting period in absence of the mitigation actions,
- *to comply with B*: an indefinite time series of annual NGHGIs is accounted for.

Approach II (used under the Kyoto Protocol): Compare projected estimates of legacy emissions and removals with actual NGHGI emissions and removals, where:

[51] It stands for "Accounted Quantities for Mitigation Results".
[52] This is usually referred as base year, reference level, or baseline.

- *to comply with A*: the legacy emissions and removals associated with historical activities and disturbances that occurred on the land before the onset of the mitigation action[53] are projected, quantified, and included within the counterfactual (baseline) value,
- *to comply with B*: an indefinite time series of annual GHG inventories is accounted for.

Approach III (used under REDD-*plus*): Compare average long-term C stock of a land under two different land uses and/or management systems of practices[54][55], where:

- *to comply with A*: it is implicitly assumed that C stocks on the land are at their long-term level,
- *to comply with B*: the overall impact of the mitigation action on the so-called long-term C stock of the land is reflected by the quantified changes during the monitoring period.

To deal with natural disturbances, the accounting approach has a single condition to be satisfied to ensure that non-anthropogenic emissions and removals are accounted for as zero, and that no anthropogenic emissions and removals are excluded from accounting:

- the amount of CO_2 emissions[56] (CO_2E_{ND}) and CO_2 removals (CO_2R_{ND}) reported as associated with natural disturbances must average out[57] across time ($CO_2E_{ND} = CO_2R_{ND}$).

Within an accounting framework like the Kyoto Protocol, such condition is satisfied through accounting as zero the GHG emissions associated with a natural disturbance, but also counting as zero all subsequent CO_2 removals until the C stocks on the same land achieve pre-disturbance levels. Although the lag in the residence time of C stocks has a temporary[58] impact on atmospheric CO_2 concentration, the approach excludes from accounting such temporary impact, since it is neither caused nor materially influenced from the mitigation action to be accounted for (see also Box 1, page 7).

[53] This means that emissions and removals from the mitigation actions are never included in the projection
[54] This is the approach applied in the Method & Guidance Documentation of the Global Forest Observation Initiative (MDG-GFOI at http://www.gfoi.org/methods-guidance/) for REDD-plus activities
[55] This approach also corresponds to the IPCC default Tier 1 methodological approach to estimate net C stock changes in the soil organic matter of mineral soils as consequence of changes in the land use and/or in the land management system of practices. This methodological approach uses the two values of long-term average SOC at equilibrium associated with use and management of the land before and after the change to estimate the net C stock change across a transition period.
[56] The other two GHG, CH_4 and N_2O, decay in the atmosphere to other compounds so that their emissions balance always to zero across the 100-year time frame of GWPs.
[57] This is the approach implemented in the 2013 IPCC KP Supplement (http://www.ipcc-nggip.iges.or.jp/public/kpsg/index.html)
[58] This means that the C stocks of the land remain within their long-term level.

Summary: Accounting for mitigation actions in the land use sector

- Mitigation results (AQ_{MR}) are deviations associated with actions aimed at reducing the atmospheric concentration of GHG or avoiding further increases. Thus, they are accounted by subtracting the expected GHG fluxes ($GHG_{EXPECTED}$), i.e. the counterfactual (baseline) value, from actual GHG fluxes (GHG_{ACTUAL}), i.e. what the atmosphere has seen, $AQ_{MR} = GHG_{ACTUAL} - GHG_{EXPECTED}$.

- In the land use sector, the contribution of legacy emissions and removals, as well as emissions and removals from natural disturbances, should be accounted as zero, since they are not associated with the implemented mitigation actions.

- To zero out the contribution on mitigation results of legacy emissions and removals associated with activities and disturbances that occurred on the land before the implementation of the mitigation actions, and to count all legacy effects of the implemented mitigation actions, either:

    Legacy emissions and removals across the total national land territory are assumed to be stable throughout the indefinite time series of GHG inventories that are accounted;

    Legacy emissions and removals caused by pre-implementation activities and disturbances are projected as expected to occur under BAU conditions and accounted through an indefinite time series of GHG inventories;

    Or C stocks are assumed to be at their long-term equilibrium and the entire difference in long-term C stock caused by mitigation actions is accounted during the monitoring period.

- To zero out the contribution of natural disturbances, the amounts of CO_2 emissions and removals associated with natural disturbances and accounted for should balance out.

Summary of Sections 1 to 5

In the previous sections, the nature of CO_2 emissions and removals, as well as the drivers of such emissions and removals have been discussed, with the following conclusions:

- Any CO_2 emission from fossil fuels, including peat[59], is a net addition to the atmosphere-land-ocean (biosphere) system and results in a proportional[60] increase of atmospheric CO_2 concentration;
- CO_2 emissions from terrestrial C pools (i.e. land use sector) may be either:
    - A *temporary* increase in atmospheric CO_2 concentration if the long-term C stock of the land of origin does not change. This is the case if the emission is a consequence of a natural disturbance or a sustainable management practice where the CO_2 emitted will be balanced out across time by subsequent CO_2 removals from the land; or
    - A *permanent* increase in the atmospheric CO_2 concentration. This is the case if the emission is consequence of a change in the land use and/or management system that determines a decrease of the long-term C stock, since the CO_2 emitted is not expected to be balanced out by subsequent CO_2 removals from the land.
- Similarly, CO_2 removals from terrestrial C pools may cause either a permanent or a temporary decrease of the atmospheric CO_2 concentration, depending on whether they are associated with an increase of the long-term C stock or not.
- Whether from fossil fuels or terrestrial C pools, an emission avoided within a time frame can subsequently occur—resulting in a reversal—if its drivers have not been permanently addressed.
- Similarly, any CO_2 removal associated with an increase of the long-term C stock may be subsequently reversed if the drivers that previously impeded such increase have not been addressed permanently.
- NGHGIs include a time series of all national GHG emissions and removals. They aim to include only those caused by the national socio-economic system (i.e. anthropogenic fluxes) and reflect the impact of such systems on the atmospheric GHG concentration. Within the time series the temporality/permanency of GHG fluxes is properly reflected such that the sum of the time series corresponds to the actual net impact in the atmospheric GHG concentration caused by the country, from the first year till the last year of the time series.
- Changes in the NGHGI trend provide information on achieved reduction of emissions and/or enhancement of C stocks.

[59] See Box 4, page 8 for details on peat as a fossil C stock

[60] According to Le Quéré, C. et al (2018). Global Carbon Budget. *Earth Systems Science Data 10*, 405-448 - http://www.globalcarbonproject.org/, 44% of the annual CO_2 emissions accumulate into the atmosphere, 31% are sequestered by terrestrial C pools (mainly forests) and 25% by oceans.

6. Permanence of accounted quantities

In this section the permanence of accounted quantities is analyzed. Accounted quantities are the reduced emissions, or the enhanced C stocks, achieved and measured during an accounting period against a counterfactual[61] baseline level.

There is no official definition of permanence under the UNFCCC. However, within the UNFCCC, permanence was first discussed within the Clean Development Mechanism of the Kyoto Protocol (CDM), in relation to net C stock accumulation accounted in afforestation and reforestation project activities (AR-CDM). Because project activities have a limited timeline, there is no certainty that achieved results will persist after the end of the project activity. Such uncertainty stems from the lack of knowledge about the future use of the land, i.e. whether the drivers (e.g. alternative use of forest land) have been addressed by the project activity temporarily or permanently. For such reason accounted units expire at the end of the monitoring period[62].

Subsequently, permanence was discussed again under the CDM in relation to avoided emissions from Carbon Capture and Storage (CCS) project activities. Avoided emissions by CCS are considered to have been permanently achieved 20 years[63] after the end of the crediting period[64] (i.e. from 20 to 39 years after the emission has been avoided). This means that it is assumed, after 20 years, that the likelihood of a reversal of results (e.g. emissions' leakage from geological deposits) is negligible—i.e. all the CO_2 is assumed to have permanently moved from the system atmosphere-land-ocean to the geological deposit. Thus, because the CO_2 is no longer considered part of the atmosphere-land-ocean system, the accounted units do not expire and are considered permanent.

Permanence of mitigation results is therefore an issue that stems from the limited time scale of mitigation activities compared with the time frame of the UNFCCC's objective to stabilize atmospheric GHG concentration at a level that does not seriously harm human socio-economic systems as well as natural ecosystems. It is a problem relevant for any accounting system where those that issue emission reductions are not liable for reversals that occur beyond the monitoring period. In other words, when a non-permanent unit is accounted, it does not correspond to actual mitigation, and consequently undermines the integrity of the accounting framework.

Thus, when discussing permanence of mitigation results, the time frame of the accounting mechanism determines whether there is a gap in the liability for any subsequent reversal of accounted results. The UNFCCC[65] and its associated Kyoto Protocol[66] and Paris Agreement[67] all reference long-term achievement of results. The IPCC, in its AR5[68] and in the special report on CCS[69], uses the word "long-term"[70] to

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[61] The GHG emissions and removals that would occur in absence of mitigation.
[62] See section F. for a description of the provisions implemented under AR-CMD to address non-permanence of accounted units
[63] See UNFCCC decision 10/CMP.7
[64] The crediting period is the period during which achieved mitigation results are accounted and, if verified emission reductions have occurred, mitigation units are issued.
[65] "...modifying long term trends in anthropogenic GHG [net] emission…"
[66] "...long term benefits related to mitigation…"
[67] "…long term temperature goal…" and "…long term low GHG [net] emission development strategies…"
[68] 2013, IPCC 5th Assessment report. Working Group 1: The physical Science Basis (http://www.ipcc.ch/report/ar5/wg1/)
[69] 2005 IPCC Special Report on Carbon Dioxide Capture and Storage (http://www.ipcc.ch/report/srccs/)
[70] The very long-term objective is to further reduce it towards pre-industrial levels.

indicate the time period needed to achieve stabilization of atmospheric CO_2 concentration at a safe level[71], and establishes that a long-term result is one achieved up to the end of this century.

For NGHGIs, the IPCC has implicitly established a 100-year time frame by estimating the global warming potential (GWP) of each GHG as the average[72] warming effect caused across a century. So, consistent with the UNFCCC's objective, NGHGIs report levels and trends of anthropogenic GHG emissions and removals, with the aim to assess: (a) the contribution of human activities to the (increasing) concentration of GHG into the atmosphere, and (b) the results of implemented mitigation policies and measures.

Further, in its special report[73] on Land Use, Land-Use Change, and Forestry, the IPCC defines Permanence as: "The longevity of a C pool and the stability of its stocks, given the management and disturbance environment in which it occurs"[74]. The "long-term C stock," as defined in this report, fully corresponds to such description. It measures the "permanent" negative[75] (or positive) contribution of the land to the atmospheric CO_2 concentration, taking into consideration the impact of the management system of practices and of the natural disturbances regime.

In summary, consistent with the IPCC and UNFCCC reporting framework, the following can be considered as permanent results from mitigation actions:

- the avoidance of GHG emissions from fossil fuels, including peat, if the driver of such emissions is permanently addressed by the action (i.e. transformational changes);
- the avoidance of CO_2 emissions from fossil fuel combustion through CCS if 20 years have passed without reversal, i.e. the carbon is considered to reside permanently in the geological deposit
- the avoidance of GHG emissions from land, if the new use and/or management system of practices does not revert i.e. the long-term C stock does not decrease;
- the sequestration of CO_2 removals, so far as it is associated with an increase of the long-term C stock.

Since mitigation activities are always implemented for a shorter time period than a century, their results may not be considered permanent, with the exception of CCS, unless the liability for potential reversal beyond the end of the monitoring period of the activity is addressed.

Conversely, if mitigation activities occur within the scope of coverage of a long-term national commitment i.e. within the NDC as a strata/subdivision of the NGHGI's categories, permanence would be addressed as liability would reside with the activity implementers until the end of the monitoring period, and then would be transferred to the country thereafter.

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[71] This level is currently established around 450 ppm of CO_2 atmospheric concentration (IPCC AR5, 2014 - https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf)
[72] GWPs are calculated in function of the warming effect and of the GHG's resident time in the atmosphere.
[73] 2000 IPCC Special Report on Land Use, Land-Use Change, and Forestry (available at www.ipcc.ch/ipccreports/sres/land_use/index.php?idp=0).
[74] It further discusses: "Enhancement of C stocks resulting from land use, land-use change, and forestry activities is potentially reversible through human activities, disturbances, or environmental change, including climate change. This potential reversibility is a characteristic feature of LULUCF activities in contrast to activities in other sectors. This potential reversibility and non-permanence of C stocks may require attention with respect to accounting, for example, by ensuring that any credit for enhanced C stocks is balanced by accounting for any subsequent reductions in those C stocks, regardless of the cause".
[75] i.e. the amount of CO_2 subtracted permanently from the atmosphere since stored for long term in the C pools.

Summary: Permanence of accounted quantities

- There is no official definition of Permanence under the UNFCCC, although it has been discussed in relation to liability for reversal of accounted mitigation results (e.g. within the CDM, for Afforestation/Reforestation and Carbon Capture and Storage project activities).

- With the exception of net emission reductions achieved through CCS, any mitigation result may be reverted if the drivers of emissions are not permanently addressed by the mitigation action.

- Under the UNFCCC and IPCC reporting framework the timeline for long-term (permanent) results is the century. Accordingly:

  Mitigation activities may not account for permanent results unless liability of potential reversal beyond the monitoring period is addressed (CCS is an exception);

  Results accounted through NGHGIs are permanent, since the long-term time frame of NGHGIs ensures that any reversal that occurred within the century would be accounted. This assumes that a country does not step away from accounting of its commitment under the UNFCCC.

- If the scope of mitigation activities falls within national accounting for an NDC (e.g. a forest carbon project occurs on land within a country that accounts in its NDC for the same forest land), permanence may be addressed by shifting liability from the short-term project to the long-term national commitments of the country in which the project resides.

7. Addressing the risk of non-permanence under the UNFCCC

Under the UNFCCC the risk of non-permanence of accounted results has been so far recognized for Kyoto Protocol-LULUCF activities and for AR and CCS project activities under the CDM. For other CDM activities, non-permanence has not been considered an issue. This is because either the project activity is assumed to permanently addresses the drivers of emissions, e.g. when a renewable energy power plant is built, or because it has been implicitly assumed that emissions occurring after the end of the project implementation are not associated with the project itself, e.g. when a bioenergy power plant drives in a region the overexploitation of biomass stocks.

UNFCCC provisions are aimed at addressing the risk of non-permanence, instead of just minimizing, its impact on accounting. Thus, for Kyoto Protocol accounting, the risk of non-permanence is addressed by:

- stating that once a land is accounted it must stay within the accounting forever[76], and reported within the NGHGI. This means that any reversal is reported in the NGHGI and accounted in the year(s) in which it occurs;
- requiring countries that experience natural disturbances in a given year—and that take out of the accounting emissions from such a disturbance event—to also take out of the accounting in subsequent years the regrowth that occurs up to the same amount;
- issuing temporary credits for AR-CDM project activities that expire at the end of the monitoring period (although they can be renewed for subsequent crediting periods). This means that any future reversal is pre-emptively accounted at the end of the monitoring period. It is worth noting that: (a) such a solution likely leaves a portion of mitigation results unaccounted, since forest may need a period longer than the established monitoring period to fully account for the increase in the long-term C stock and (b) although all or a fraction of the C stock increases to long-term, all mitigation results are accounted for as temporary because of the precautionary principle[77];
- ensuring the monitoring of CCS-CDM project sites for the 20-year period subsequent to the end of the crediting period (after which the risk of reversal is assumed to be zero)[78]. CCS-CDM project activities also minimize the risk of non-permanence between the end of the project accounting period and the end of the monitoring period through reserving 5% of accounted quantities to offset any leaked emission. This, however, leaves unaddressed the risk of non-permanence of leaked emissions beyond the 5% threshold.

Within the Paris Agreement, non-permanence is addressed by requiring that “Parties strive to include all categories of anthropogenic emissions or removals in their nationally determined contributions and, once a source, sink or activity is included, continue to include it”[79]. In other words, any subsequent reversal of results should be reported and accounted for (in the year in which it occurs).

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[76] This ensures that any reversal is reported and accounted.

[77] Since a fraction of the accounted C stock net increase may be just temporarily stocked, for precaution the entire C stock is considered just temporarily stocked.

[78] However, it is recognized that, in the very long term, CO_2 stored in deposits under oceans may have an impact on atmospheric CO_2 by first saturating sea water.

[79] Decision 1/CP.21, para 31c. Considering that both land and C pools may be either a source or a sink, it may be implied that once a land or a C pool is included in the NDC accounting it must be accounted forever.

Summary: Addressing the risk of non-permanence under the UNFCCC

- Under the UNFCCC, the risk of non-permanence is addressed in accounting frameworks through indefinite reporting (through NGHGIs) and accounting (through NDCs);

- For the land use sector, such a risk is further addressed by:

  in national accounting, ensuring that once a land/pool/activity is accounted, it must remain within the accounting in perpetuity; and

  in project activities, issuing temporary mitigation units that may be renewed so far as GHG emissions and removals from accounted land/pools are monitored.

- Under the Paris Agreement, permanence is addressed so long as land/pools/activities accounted for in any NDC are accounted for in all subsequent NDCs. Consequently, accounted net emission reductions, including those achieved through CO_2 removal, are permanent.

8. Addressing the risk of non-permanence under other accounting frameworks

There are a number of other accounting frameworks, outside the UNFCCC, that have adopted approaches to deal with the risk of non-permanence. The development of such approaches is necessary because of the mismatch between the (short) timeframe of projects or programs seeking crediting and the (longer) time horizon across which permanence of accounted results need to be ensured. Such approaches vary, but are usually a combination of measures that:

- Aim to reduce the *risks* of non-permanence when accounting over shorter time-frames:
    - Program design requirements (e.g. to demonstrate transformational change)
    - Insurance mechanisms (e.g. buffer accounts or pooled reserve)
- Address non-permanence, such as:
    - Requirements for monitoring for long periods
    - Liability for reversal

Many programs include requirements related to program design, i.e. demonstration that the underlying project or program that is generating emission reductions or removals has been designed to ensure long term storage of C stocks. For example, the Forest Carbon Partnership Facility's Carbon Fund requires countries to demonstrate "how effective Emission Reduction Program design and implementation will mitigate significant risks of reversals … and will address the sustainability of Emission Reductions." The Verified Carbon Standard also requires such 'sustainable' program design through the required application of a "non-permanence risk tool" which scores a program based on a range of risk types and does not allow high risk projects to proceed. In addition, the ratio of units required to be placed in the buffer pool (see paragraph below) is determined by the project's scoring on permanence risk, which incentivizes the mitigation of reversal risks through good project design.

Most crediting or payment mechanisms (e.g. the Verified Carbon Standard, Forest Carbon Partnership Facility's Carbon Fund, California's cap-and-trade system) require projects or programs seeking to issue emission reductions (or credits) to establish a reserve of accounted units to be used to offset any reversal. These are often pooled into a 'buffer' reserve or account which may then be used in the instance of a reversal. Some accounting frameworks only allow the buffer to be used in the case of a natural disturbance, or force majeure[80], event (while placing liability for 'intentional' reversals on the project proponent or land owner). The number of units required to be placed in the reserve is estimated based on an analysis of the likelihood of a reversal. For example, a risk analysis may be based on: lack of broad and sustained stakeholder support, lack of institutional capacities and/or ineffective vertical/cross sectorial coordination, lack of long-term effectiveness in addressing underlying drivers, the lack of unambiguous assignment of carbon rights, the exposure and vulnerability to natural disturbances (although the latter is not a cause of non-permanence so far as the disturbed forest is allowed to grow again till its pre-disturbance status). Finally, a reserve account reduces the risk of reversals, but only ensures permanence of an amount of units equivalent to the quantity of reserved units it contains since all reversals exceeding such amount would not be offset—although such risks can be mitigated through a pool of credits drawn from a diversified set of projects.

[80] While "natural disturbances" indicates the fraction of GHG emissions and removals that occur in a managed land although not associated with human actions, "force majeure" indicates GHG emissions and removals that have an anthropogenic component although driven by a necessity caused by one or multiple natural factors.

A few systems have more stringent rules to address permanence, through legal liabilities placed on project proponents and/or land owners. California's cap-and-trade system defines permanence as lasting for 100 years. A forest carbon project must monitor, verify, and report offset project data for 100 years following any year a credit is generated and issued. For example, if a credit is issued in year 25 of a project, monitoring and verification would have to last for a total of at least 125 years. Furthermore, there is a regulatory obligation[81] for all intentional reversals (e.g. from land conversion, over-harvesting or other negligence) to be compensated through retirement of other compliance instruments[82]. Similarly, the Australian Emissions Reduction Fund requires any carbon uptake underlying issued credits to be stored for at least 100 years—or 25 years with a 20% discount on credits. A land owner may choose to cancel a project at any time but, in doing so, is required to relinquish all credits as well as use credits from another project or purchase an equivalent amount at market price, to replace any credits already sold. In both instances (California and Australia), these provisions are in addition to participating in a buffer pool, i.e. projects are also required to place a percentage of emission reductions achieved into a reserve, which is used only for 'unintentional reversals', primarily natural disturbances, while the project proponent or land owner is fully liable for any intentional reversal.

Summary: Addressing the risk of non-permanence under other accounting frameworks

Other accounting frameworks have developed systems and tools to manage the risk of reversals:

- Requiring projects or program to contribute to a buffer reserve account (a kind of pooled insurance mechanism), particularly for use in 'unintended reversals' (force majeure events, e.g. natural disturbances); such a mechanism only ensures permanence up to the number of units in the reserve;
- Requiring specific elements to be included in the project/program activity and/or design that minimize the risk for reversals;

Or to address non-permanence:

- Monitoring and verification for a long-term period considered to ensure permanence, e.g. up to 100 years;
- Providing clear liability for 'replacement' of accounted units for any instance in which a reversal occurs.

[81] Regulation for the California Cap on Greenhouse Gas Emissions and Market-Based Compliance Mechanisms (https://www.arb.ca.gov/cc/capandtrade/capandtrade/unofficial_ct_100217.pdf)
[82] If the forest owner does not provide offset credits for retirement equal to the reversal amount, then California's Air Resources Board retires the difference and the forest owner is considered in Violation of the regulation and subject to enforcement action.

9. Conclusion: Forests in accounting frameworks for mitigation

This paper discusses, from a technical perspective the issue of “permanence” subjects and demonstrates that mitigation achieved through long-term gains of C stocks in forest land is as permanent as it is the one accounted as reduction of fossil fuels use due to transformational changes. All elements discussed have been generalized to the land use sector, since forest land is just a subdivision of it.

The report starts from recalling the meaning of “non-permanence” as the reversal of an achieved result, while its opposite, “permanence,” indicates the quality of a result lasting through time. In relation to the UNFCCC, permanence has been implicitly used to for two aspect of mitigation results: the permanence of an emission (i.e. its resident time into the atmosphere) or of a CO2 removal or emission reduction (i.e. its resident time into the C pools). Permanence may also be related to the driver(s) causing the emission and/or removal, or the likelihood that the driver(s) counteracted by the mitigation action will be active again. In other words, the impact of a CO2 molecule on global warming is a function of its resident time in the atmosphere or C pool, and therefore also a function of the drivers that determine its transfer from C pools to the atmosphere and vice versa. For the land use sector, this means that the long-term C stock of a land represents its permanent impact on the atmospheric CO2 concentration.

In the land use sector, drivers of emissions and removals are both natural and anthropogenic. While emissions and removals associated with natural disturbances can be assumed to balance out across time and thus are in their nature non-permanent, those caused by human actions can permanently change the long-term C stock level of a land, or may just temporarily change it if drivers of C stock degradation reverse back once the action (e.g. halting illegal logging) is ceased. The permanent or temporary nature of a C stock change as well as of an emission generated using fossil fuels is determined by the permanence of the impacts of the human actions on the drivers that were generating such C stock changes or emissions. Transformational changes are those that permanently address drivers of C stock changes and/or emissions and therefore ensure permanence of mitigation results.

To date, some have claimed that the non-permanence of mitigation results achieved though forest activities is a barrier for the full inclusion of forests, and of the entire land use sector, within various frameworks that account for mitigation.

Nevertheless, the Paris Agreement requires countries to take economy-wide targets, which encompass forests and the entire land use sector, without further consideration of permanence. This is because of the assumed long-term nature of NDC commitments based on the reporting of all managed land and their associated GHG emissions and removals. This long-term nature of commitment based on comprehensive NGHGIs ensures that the accounted mitigation corresponds to what the atmosphere has seen as results of the actions. Any reversal of an accounted quantity under such a system would be accounted in the year in which it occurs, so that at any point in the time series the accounted result of mitigation actions corresponds to the net impact those actions have had on the atmosphere.

Conversely, the exclusion from an NDC of terrestrial C stocks, especially those in forest land, very likely will result in biases in the accounted quantities. In particular, current reporting rules in the energy sector allows accounting of emission reductions in the sector through replacement of fossil fuels with biomass, at the expense of the GHG budget of the land use sector. Further, materials that requires the use of energy and/or causes emissions along their production chain, as for instance aluminum, steel, cement and plastics, can be replaced by wood and other biomaterials, again at the expenses of the GHG budget in the land use sector. In practice, mitigation achieved in the energy and/or industrial sectors might be the result of a mere shift of emissions to forests or land within or even outside the boundaries of the NDC.

For such reason, accounting mechanisms that de-link forests and land, i.e. make forest/land not fully fungible with other sectors, must be avoided to be serious in tackling climate change.

Terrestrial sinks (mostly forests) currently remove around 30% of human-caused CO_2 emissions and are the only carbon capture and storage approach proven to work at scale and reasonable cost. A recent study illustrated how large-scale reforestation and forest restoration efforts in China, India and South Korea resulted in sequestration that exceeded 12 billion tCO_2 at relatively low costs (from USD $2 to around $26/ton)83. This is compared to current costs of technological solutions, such as direct air capture, that cost over $500/ton84.

Furthermore, terrestrial C pools, especially forest land, contains such a large stock of carbon, even larger than that of fossil fuels reserves, that their exclusion from mitigation actions can seriously jeopardize or even annul mitigation results achieved in other sectors. Emissions from terrestrial C pools caused by humans as well as the impact of climate change itself on such C pools could be significant—on the order of those from fossil fuels. To tackle such GHG fluxes and their risks, the only currently available instrument is the mitigation framework under the UNFCCC. Failing to use it exposes humankind to impacts caused by high atmospheric CO_2 concentration and associated climate changes.

This report therefore advocates for the full inclusion of forests in the nationally determined contributions of countries, and for taking actions to prevent long-term C stock losses in forest land and to enhance such long-term C stocks. Such full inclusion will not only preserve the environmental integrity of NDCs, it will also prevent accounting as mitigation the mere shift of emissions from a sector included in the NDC to a sector excluded, or delinked, from such NDC.

[83] Wolosin, M. (2017). Large-scale Forestation for Climate Mitigation: Lessons from South Korea, China and India.
[84] Some studies indicate that such costs may be declining, but are still above the costs of reforestation (see: https://www.sciencemag.org/news/2018/06/cost-plunges-capturing-carbon-dioxide-air)