# Estimating the mitigation potential of forest landscape restoration

## Practical guidance to strengthen global climate commitments

Simon König, Erin D. Matson, Elmedina Krilasevic and Maria Garcia Espinosa

INTERNATIONAL UNION FOR CONSERVATION OF NATURE

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Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

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Our sincere gratitude to Carole Saint Laurent on the guidance provided throughout the publication development process.

# List of abbreviations and acronyms

| | |
|---|---|
| **AFOLU** | Agriculture, Forestry and Other Land Use |
| **BUR** | Biennial Update Reports |
| **C** | Carbon |
| **$CH_4$** | Methane |
| **$CO_2$** | carbon dioxide |
| **ER** | emission reduction and removal |
| **FLR** | Forest Landscape Restoration |
| **FREL** | Forest Reference Emission Levels |
| **GHG** | greenhouse gas |
| **IPCC** | The Intergovernmental Panel on Climate Change |
| **IUCN** | International Union for Conservation of Nature |
| **LULUCF** | Land Use, Land-use Change and Forestry |
| **NC** | National Communications |
| **NDC** | Nationally Determined Contribution |
| **NIR** | National Inventory Report |
| **$N_2O$** | Nitrous oxide |
| **REDD+** | Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries |
| **UNFCCC** | The United Nations Framework Convention on Climate Change |

# Glossary

**AFOLU** — **Agriculture, Forestry and Other Land Use.** For the 2006 IPCC Guidelines, agriculture was incorporated with LULUCF into the IPCC's new land-use framework, AFOLU. In addition to the categories included in LULUCF, AFOLU includes agricultural practices such as fertiliser application, rice cultivation and livestock-related emissions such as enteric fermentation and manure management. For use in the common reporting format (CRF) for Annex I country submission of National GHG inventories.

**Baseline** — The baseline or reference level of carbon stocks or GHG emissions in a landscape against which additional gains or losses are measured. The baseline is generally assumed to be the stocks and emissions levels that exist before a given intervention is undertaken. A baseline approach holds other values in the landscape constant and focuses on the avoided costs or captured benefits of a single intervention.

**BUR** — **Biennial Update Reports.** BURs are submitted by non-Annex I parties to the UNFCCC every two years. These reports contain updates on information from the NCs, particularly regarding GHG inventories, mitigation actions, needed resources or capacity to address constraints and gaps and support received. Each BUR contains, at a minimum, the inventory for a calendar year no more than four years prior to the date of submission.

**C** — **Carbon.** Vegetation sequesters $CO_2$ from the air and stores it as carbon in biomass and soils. $CO_2$ values are converted to C according to the respective molecular weight as $C = CO_2 / (44/12)$

**Carbon pool** — A system that has the capacity to store or release carbon. The Marrakesh Accords recognise five main carbon pools or reservoirs in forests: above-ground biomass, below-ground biomass, dead wood, litter and soil organic matter.

**Carbon stock** — Volume of carbon stored in a carbon pool.

**$CH_4$** — **Methane.** A greenhouse gas that, in the land sector, is emitted through certain land-use practices such as enteric fermentation that takes place in the digestive systems of ruminant livestock, certain rice cultivation methods, manure and wetland management. While considered a short-lived climate pollutant and at lower concentration levels in the atmosphere, methane has a high radiative forcing effect that in results in increased potential for global warming.

**$CO_2$** — **Carbon dioxide.** A greenhouse gas (GHG) that, in the land sector, is emitted as a result of processes including respiration, oxidation, biomass decay and burning. Deforestation, forest and land degradation are common causes. Conversely, FLR practices can sequester/remove $CO_2$ from the atmosphere and enhance carbon stocks.

**Emissions** Greenhouse gases emitted to the atmosphere commonly expressed in $CO_2$ equivalent ($CO_2e$)

**Emission factor** Amount of a certain GHG released to the atmosphere for a given unit and time frame such as $tCO_2$/ha/yr

**FREL** **Forest Reference Emission Levels.** FRELs serve as a benchmark to assess country performance in REDD+ activities. Countries must set reference levels to receive results-based payments for emissions reductions. FRELs are reported in tonnes of $CO_2$ equivalent per year for the reference period and are calculated using IPCC guidance consistent with the national GHG inventory.

**GHG Inventory** Annual national greenhouse gas (GHG) inventories account for the direct GHG emissions and removals from five sectors, including agriculture and land use, land-use change and forestry. For Annex I countries, the GHG inventories are submitted every year in two parts: the common reporting format (CRF) tables, which contain quantitative information and the National inventory report. For non-Annex I countries, GHG inventories are updated in national communications and biennial update reports.

**IPCC** **The Intergovernmental Panel on Climate Change.** The IPCC is an international assessment body established in 1988 to provide the world with a clear scientific view on the current state of knowledge in climate change and the potential environmental and socio-economic impacts. The IPCC provides guidance on estimating GHG emissions, removals and stocks that countries have used to report to the UNFCCC since 1996. Good Practice Guidance published in 2003 for the land use, land-use change and forestry sectors provides methodologies to estimate changes in five carbon pools (above-ground biomass, below-ground biomass, dead wood, litter and soil organic matter) and non-$CO_2$ emissions for six land-use categories and for land-use changes. These methodologies can be employed at three levels of detail, called "tiers." Tier 1 is the least detailed and is also called the "default method," designed to be implemented by any country. Tiers 2 and 3 require progressively more detailed and country-specific information based on field work and/or high-resolution spatial data.

**Lifetime** The period over which an FLR activity is maintained once implementation has started

**LULUCF** **Land Use, Land-use Change and Forestry.** A land-use categorisation framework codified in the 2003 Good Practice Guidelines for LULUCF; includes forest land, grassland, cropland, settlements, wetlands and other lands (e.g. ice, rock, bare soil). In each land-use category, emissions and removals are estimated from living biomass, dead organic matter and soil organic carbon.

**NC** **National Communications.** NCs are submitted by non-Annex I parties to the UNFCCC every four years. They provide information on national GHG inventories as well as measures taken for climate change mitigation and adaptation. NCs include both country-specific adaptation and mitigation assessments.

| | |
|---|---|
| **NDC** | **Nationally Determined Contribution.** As required by the Paris Agreement, the NDCs are action plans developed by countries to detail their efforts to reduce greenhouse gas (GHG) emissions and adapt to the impacts of climate change. Countries agree to review and resubmit their NDCs to the UNFCCC every 5 years, with the first resubmission in 2020. NDCs may define specific targets for the land-use sector (in terms of emissions and/or land area). |
| **NIR** | **National Inventory Report.** The NIRs contain detailed information on the GHG inventory for Annex I countries, including descriptions of the methodologies used in the estimations, the data sources, the institutional arrangements for the preparation of the inventory and recalculations and changes compared with the previous inventory. |
| **$N_2O$** | **Nitrous oxide.** A greenhouse gas that, in the land sector, can be emitted from the application of certain fertilisers, manures and compost to soils and other activities associated with livestock storage and management. Nitrous oxide is less concentrated in the atmosphere than $CO_2$ and $CH_4$ but has a much higher radiative forcing effect than both that results in increased potential for global warming. |
| **REDD+** | **Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries.** REDD+ was developed in part to slow, halt and reverse forest cover and carbon loss. REDD+ implementation follows three stages, beginning with national strategy and capacity-building, then moving to implementation and review of national strategies if further resources were provided and finally result-based actions and finance. |
| **ROAM** | **Restoration Opportunities Assessment Methodology.** A framework developed by IUCN in collaboration with the World Resources Institute for countries to identify and analyse areas with potential for Forest and Landscape Restoration (FLR) and to identify specific priority areas at a national or sub-national level. |
| **UNFCCC** | **The United Nations Framework Convention on Climate Change.** The UNFCCC is an international environmental treaty that seeks to stabilise greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous anthropogenic interferences. 195 countries have ratified the Convention, which meet yearly at the Conference of the Parties (COP). The treaty was negotiated in Rio de Janeiro in 1992 and set into force in 1994. Under the UNFCCC, countries are required to submit regularly updated GHG inventories using IPCC methodologies. |

# List of figures, boxes and tables

# Purpose

**This document aims to guide proponents and developers of forest landscape restoration (FLR) activities and programmes in the rapid estimation of FLR mitigation potential, alignment with national greenhouse gas (GHG) estimation processes and identification of opportunities to enhance the role of FLR in national mitigation efforts.** By following this guidance, the user will be able to:

1. Understand the relationship between FLR opportunities and national GHG estimation processes
2. Summarise and clearly define the identified FLR opportunities with relevance for estimating the mitigation potential
3. Identify resources for estimating mitigation potential and calculate estimates for select FLR activities
4. Identify potential gaps in the scope of national GHG estimation and NDCs while highlighting concrete opportunities for their respective enhancement
5. Ensure a level of harmonisation for mitigation potential estimates in a way that could facilitate global aggregation to demonstrate the mitigation potential across countries or regions
6. Generate awareness and communicate the mitigation potential of contemplated FLR activities including towards the achievement of Nationally Determined Contributions (NDCs) and Bonn Challenge targets
7. Provide a basis for reporting progress against restoration goals that may have been defined under NDCs, initiatives such as the Bonn Challenge or the New York Declaration on Forests.

**A number of useful tools exist for estimating the GHG and carbon impacts of land-use activities.[1] These tools allow for an in-depth estimation of certain FLR activities using global or regionally-specific data.** To varying degrees they generate estimates that are sufficiently reliable to serve for national and sub-national GHG reporting. However, such tools

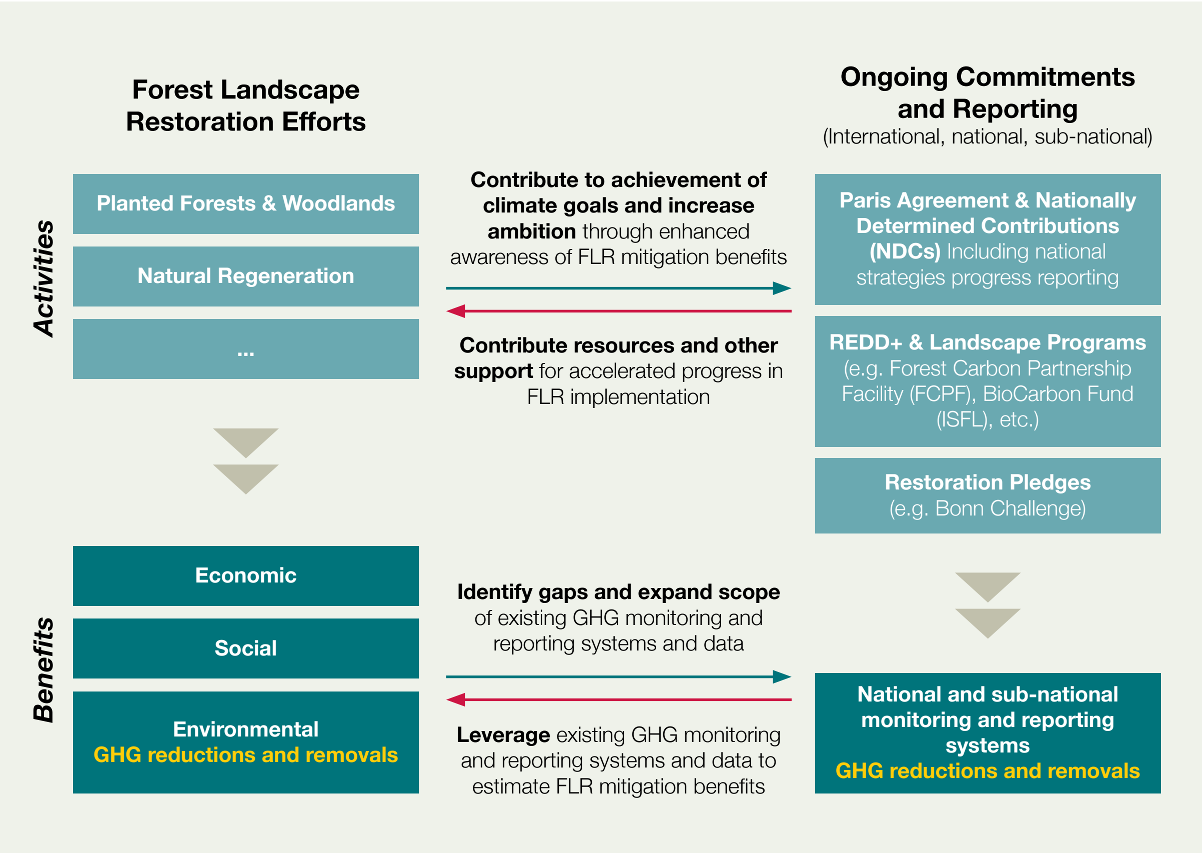
1 Available tools include the Ex-Ante Carbon-balance Tool (EX-ACT) from the Food and Agriculture Organization of the United Nations (http://www.fao.org/tc/exact/ex-act-home/en/); the Forest Landscape Restoration Climate Impact Tool developed by Winrock International and IUCN (https://www.winrock.org/document/forest-landscape-restoration-climate-impact-tool/); and CarboScen, created by the Center for International Forestry Research (CIFOR) (https://www.cifor.org/gcs/toolboxes/carboscen/).

typically require a sophisticated understanding of GHG estimation processes and highly detailed information FLR activities. These tools and the guidance document are complementary. They can be used in combination specifically to strengthen identification of FLR interventions and corresponding land use transitions relevant for GHG estimates. However, the guidance can be used independently to generate estimates tailored to the specific needs of individual FLR programs.

**This guidance fills a gap by placing specific emphasis on: 1) aligning FLR mitigation potential estimation with existing national and sub-national processes and; 2) creating a cost-effective preliminary estimation of long-term mitigation benefits.** These early estimates are suitable for leveraging additional support for FLR and highlighting mitigation potential to inform national and sub-national GHG estimation processes and commitments.

***Figure 1* illustrates the potential for mutually reinforcing relationships between the efforts of FLR proponents and ongoing programmes, processes and commitments at the international, national and sub-national level.** This figure is not comprehensive but aims to illustrate opportunities for how the outputs from applying this guidance could be utilised.

**Figure 1: Relationship between FLR planning and climate and restoration commitments**



# The role of forest landscape restoration in mitigating climate change

**The Forest Landscape Restoration (FLR)[2] approach can be applied to land use planning and management in order to regain the ecological and productive functionality of landscapes. It encompasses a wide range of economically, environmentally and socially beneficial land use activities on agricultural, forest and deforested lands**, brought together in a land use mosaic. Some examples of individual FLR interventions on land include planted forests and woodlots, assisted natural regeneration, silviculture, agroforestry, improved fallows, establishment of trees on farms, mangrove restoration, watershed protection and erosion control measures. For climate mitigation, FLR utilises the natural carbon cycle to increase terrestrial carbon storage in vegetation and soils.

**The potential of FLR activities to remove $CO_2$ from the atmosphere – and avoid emissions by reducing pressure on natural forests – is becoming increasingly important** as governments, civil society organisations and private sector players are looking for pathways to meeting the 1.5°C goal formulated under the Paris Agreement. Carbon stock enhancements from natural climate solutions including the FLR approach are urgently needed to meet the 1.5°C goal.[3] *Reference Table 1* provides examples of FLR activities in relation to land use categories used by the Intergovernmental Panel on Climate Change (IPCC) and potential impacts of those activities to GHG emissions and removals.

**FLR activities are being promoted, developed, financed and implemented by a range of programmes, initiatives and public, private and civil society organisations. However, the extent to which mitigation potential has been estimated, aligned with and leveraged for national GHG targets is limited.** Among other factors, this can be explained by the emerging nature of many national GHG estimation processes – especially for emissions and removals from land use practices – and a lack of experience of GHG estimation by many FLR practitioners. This document provides guidance to help fill this gap and raise the awareness of the mitigation potential of FLR.

2 International Union for Conservation of Nature (IUCN) (n.d.) What is FLR? *InfoFLR*. https://infoflr.org/what-flr.

3 Roe, S., Streck, C., Weiner, P.H., Obersteiner, M. and Frank, S. (2017). *How Improved Land Use Can Contribute to the 1.5 C Goal of the Paris Agreement*. Retrieved from https://www.climatefocus.com/sites/default/files/CIFF%20Report.pdf.

### Reference Table 1: Examples of FLR activities according to IPCC AFOLU land-use categories

| **IPCC AFOLU land-use category** of the FLR land use | **Subcategory (land-use transition)** *First letter indicates pre-FLR land use, second letter indicates FLR land use* | **FLR activity examples** | **Potential GHG impacts of FLR activity** |
|---|---|---|---|
| **Forest Land (F)** | Forest land remaining forest land (FF) | - Extended rotation length in plantations & woodlots<br>- Transition to mixed species plantations<br>- Active or assisted natural regeneration of natural forest<br>- Improved management of natural forest<br>- Silvicultural treatment of logged forest | Enhanced C stocks in biomass of existing or new tree stocks and soils through improved forest management.<br>May reduce $CH_4$ and $N_2O$ emission from wildfires compared to prior land use but may increase $N_2O$ emissions from fertilizer use. |
| | Land converted to forest land (LF) | - Afforestation / reforestation<br>- New tree plantations<br>- Establishment of buffer zones | |
| **Cropland (C)** | Cropland remaining cropland (CC) | - Establishment of live fences & wind breaks on cropland<br>- Mixed plantations associated with annual crops<br>- Low density/height agroforestry systems | Enhanced C stocks in biomass of new crop, timber, shade trees and soils through tree planting and improved soil management.<br>May reduce $CH_4$ and $N_2O$ emission from wildfires compared to prior land use. May increase or decrease $N_2O$ emissions relative to prior land use depending on fertilisation regime. |
| | | - Improved fallow of croplands<br>- Improved soil management and conservation | |
| | Land converted to cropland (LC) | - Conversion of invasive species-dominated land to annual or permanent crops.<br>- Conversion of degraded pastures to annual or permanent cropland. | May be associated with gains or loss of C stock in biomass in vegetation and soils.<br>May reduce $CH_4$ and $N_2O$ emission from wildfires compared to prior land use. May increase or decrease $N_2O$ emissions relative to prior land use subject to fertilisation regime. |
| **Grassland (G)** | Grassland remaining grassland (GG) | - Silvopastoral systems<br>- Live fences, shade trees, & wind breaks<br>- Improved pastures<br>- Improved pasture management | Enhanced C stocks in biomass of replanted trees and grasses on farm. Increase soil carbon accumulation.<br>Reduced $N_2O$ emissions due to reduced fertilizer application. |
| | Land converted to grassland (LG) | - Re-establishment of native grasses on degraded cropland<br>- Conversion of invasive species-dominated land to grassland. | May be associated with loss of C stock in biomass of prior vegetation and soils.<br>May reduce $CH_4$ and $N_2O$ emission from wildfires compared to prior land use. May increase or decrease $N_2O$ emissions relative to prior land use subject to fertilisation regime. |
| **Wetlands (W)** | Peatlands remaining peatlands (WW) | - Rewetting of drained peatlands<br>- Revegetation of peatlands | Enhanced C stocks in biomass of existing or new vegetation and soils.<br>May reduce ongoing $CO_2$ emissions from oxidation in drained and disturbed wetland soils, reduce $N_2O$ emissions from fertiliser use in previous land use, but may increase short-term $CH_4$ emissions in case of rewetting activities. |
| | Flooded land remaining flooded land (WW) | - Mangrove restoration<br>- Other wetland restoration | |
| | Land converted to flooded land (LW) | - Restoration of former wetlands<br>- Establishment of new wetlands | |
| | Land being converted for peat extraction | *Implies drainage of peatland and removal of vegetation which is not aligned with the FLR approach and should be avoided.* | Reduced C stock in biomass of existing vegetation.<br>Increased $CO_2$ and $N_2O$ emission but reduced $CH_4$ emissions. |

*IPCC land use categories and potential GHG impacts adapted from Table 1.2 of Volume 4 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.*

# The importance of aligning with national and/or subnational processes

**Countries that are signatories to the United Nations Framework Convention on Climate Change (UNFCCC) are subject to GHG reporting requirements[4] and have submitted NDCs which describe proposed efforts by each country to reduce national emissions and adapt to the impacts of climate change.[5] Many NDCs include specific measures related to FLR,[6] thus the estimation of GHG emissions, potential reductions and removals from FLR-related activities is already undertaken through national processes.** Also, the activities of non-state actors (e.g., projects deriving carbon credits from voluntary carbon markets, private sector action, etc.) should be nested within and/or harmonized with state GHG monitoring and reporting systems and contribute to NDCs. **Practitioners should therefore work to leverage and align efforts.** UNFCCC GHG reporting requirements dictate that national estimation and reporting of GHGs adhere to IPCC Guidelines for National Greenhouse Gas Inventories.[7] Countries report to the UNFCCC through a range of publicly available documents, including but not limited to, those listed below in *Box 1*. It is recommended that users obtain the latest versions of country reports and **NDC submissions** as important background information and input to mitigation potential estimation processes:

4 United Nations Framework Convention on Climate Change (UNFCC) (2019). UNFCCC Process: Reporting and review under the Convention. *United Nations Framework Convention on Climate Change.* https://unfccc.int/process#:0c4d2d14-7742-48fd-982e-d52b41b85bb0:f666393f-34f5-45d6-a44e-8d03be236927.

5 UNFCCC (2019a). Nationally Determined Contributions (NDCs). *United Nations Framework Convention on Climate Change*. Retrieved from https://unfccc.int/process/the-paris-agreement/nationally-determined-contributions/ndc-registry.

6 IUCN (2018). Increasing ambition and action on NDCs through FLR. *InfoFLR*. Retrieved from https://infoflr.org/what-flr/increasing-ambition-and-action-ndcs-through-flr.

7 As of writing, the latest IPCC Guidelines were released in 2006 and are available here: https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html, with a Wetlands Supplement released in 2013. However, a new version of the IPCC Guidelines – the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories – is expected to be released in May 2019. See here for more information: https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/. All references to the IPCC Guidelines in this text should be understood to refer to the latest version of the Guidelines available.

**Box 1: Publicly available country submissions to the UNFCCC that can support ER estimation from FLR**

Country submissions to the UNFCCC provide useful sources of information that should be utilised and aligned with FLR ER estimation to enhance consistency. Drawing from the list below, find the most recent UNFCCC submission or FREL document from your country of interest. You are looking for the emission and removal factors and activity data for the country's latest greenhouse gas (GHG) inventory. This information might be embedded within a National Communication or a Biennial Update Report or might be available as a standalone National Inventory Report. If you are working in a jurisdiction with a REDD+ programme, consult the Forest Reference Emission Level document for that jurisdiction as well. Choose the most up-to-date information available for your specific region and FLR activities.

> UNFCCC documents can be found at: https://unfccc.int/documents
>
> UNFCCC REDD+ submissions (for FRELs) are available at: https://redd.unfccc.int/submissions.html

**National Communications (NC):** NCs are submitted by Annex I and non-Annex I parties to the UNFCCC every four years. They provide information on national GHG inventories as well as measures taken for climate change mitigation and adaptation. NCs include both country-specific adaptation and mitigation assessments.

**Biennial Update Reports (BUR):** BURs are submitted by non-Annex I parties to the UNFCCC every two years. These reports contain updates on information from the NCs, particularly regarding GHG inventories, mitigation actions, needed resources or capacity to address constraints and gaps and support received. Each BUR contains, at a minimum, the GHG inventory for a calendar year no more than four years prior to the date of submission.

**National Inventory Report (NIR):** The NIRs contain detailed information on the country's anthropogenic GHG emissions by sources and removal by sinks. This information includes descriptions of the methodologies used in the estimations, the data sources, emission factors used and descriptions of activity data. NIRs are therefore a valuable resource for finding emission and removal factors in line with national GHG estimation processes, as well as other assumptions used at the national level. The NIR would usually be included in the BUR or the NC for non-Annex I countries, while Annex I countries submit NIRs to the UNFCCC every year.

**Forest Reference Emission Levels (FREL):** FRELs serve as a benchmark to assess country performance in REDD+ activities. Countries must set reference levels to receive results-based payments for emissions reductions. FRELs are reported in tonnes of $CO_2$ equivalent per year for the reference period and are calculated using IPCC guidance consistent with the national GHG inventory. FRELs may or may not be as up-to-date as a country's latest NIR. However, FRELs might be a good source for more locally specific emission and removal factors.

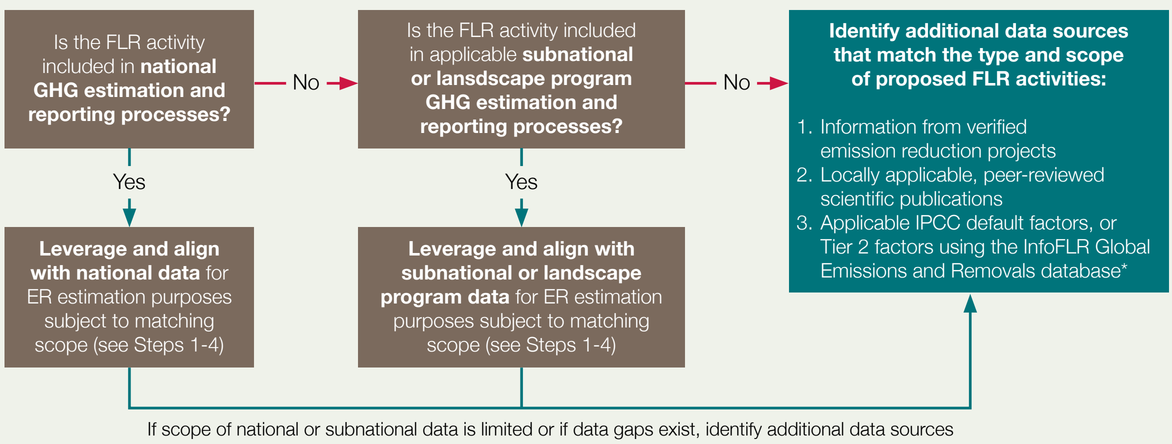
**It is important to be aware of national GHG estimation and reporting processes and recognise their importance as a resource for estimating the mitigation potential from FLR activities.** It is therefore crucial to identify the national institutions in charge of GHG estimation as well as the status of GHG estimation and reporting systems, their scope and accessibility. Ministries of environment and agriculture commonly lead GHG estimation for land use activities or at least are involved and can direct queries to the appropriate lead institutions.

**To ensure that mitigation potential estimates do not occur in isolation and effectively leverage national processes, users should identify and engage the national institutions and individuals in charge of GHG estimation.** Users should be prepared to present the scope of the FLR activities for which they intend to estimate mitigation potential. Such preparation will provide important context to individuals working on national GHG estimation and help focus the conversation, increasing the likelihood that relevant information will be provided. This effort can also lead to better integration of mitigation potential from FLR into national GHG estimation efforts.

**In addition to national programmes and processes, many sub-national governments and landscape actors have advanced in developing sustainable land use and emission reduction programmes that, if covering same geographies as the proposed FLR activities, should be identified and engaged to explore synergies regarding mitigation potential estimates.** Examples include, but are not limited to, states engaged in the Governors' Climate and Forests Task Force (GCF Task Force), emission reduction programmes (ER Programmes) developed under the World Bank's Forest Carbon Partnership Facility (FCPF) and the Initiative for Sustainable Forest Landscapes (ISFL).

**Once national GHG estimation leads and relevant sub-national and landscape programmes have been identified and engaged, users can carry out an initial assessment of the degree to which the proposed FLR activities are covered under existing GHG estimations. This process is outlined below in *Figure 2.*** The main objective of this assessment is to obtain an early indication of whether proposed FLR activities are included in the scope of national GHG estimation and reporting and hence whether information relevant to mitigation potential estimation can be obtained. If such information cannot be obtained from national and sub-national entities, the final box provides examples of where suitable data may be found.

**Figure 2: Assessment of FLR activity coverage in national GHG estimation and sub-national programmes**

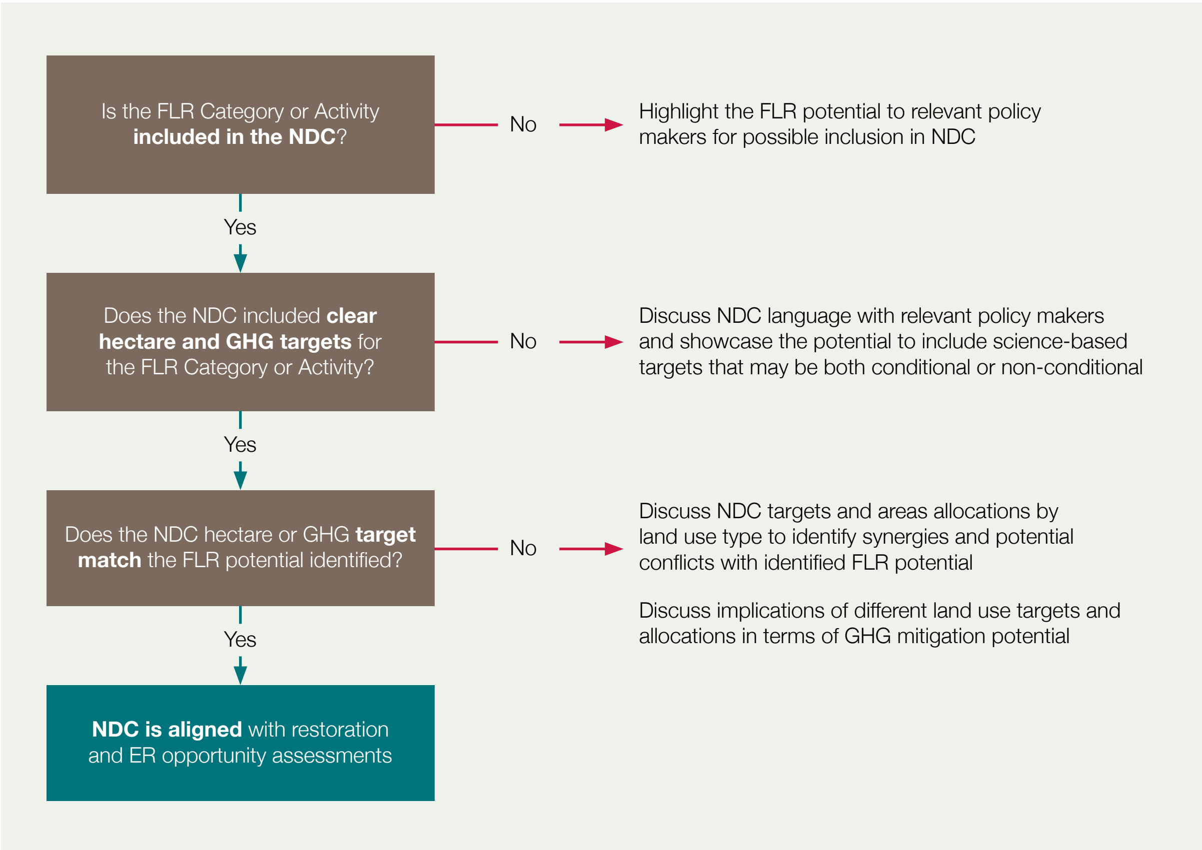



*The InfoFLR Global Emissions and Removals Database was developed by IUCN and Winrock International according to IPCC Tier 2 guidelines. It is available at https://infoflr.org/what-flr/global-emissions-and-removals-databases

**The assessment also serves to identify opportunities to enhance and complement national programmes and GHG estimation systems, landscape programmes and NDCs through inclusion of proposed FLR activities or expansion of GHG estimation scope.** *Figure 3* provides a non-exclusive and non-prescriptive example of potential NDC enhancement opportunities that may be identified as a result of mitigation potential estimation processes using this guidance. A similar assessment may be carried out for identifying opportunities for enhancing sub-national or landscape programmes with FLR activities and associated mitigation potential estimates.

**Users seeking to credit, trade and/or seek payment for mitigation outcomes through carbon markets are encouraged to utilise existing GHG standards for voluntary or regulated emission trading markets and associated methodologies including but not limited to the Verified Carbon Standard (VCS),[8] Gold Standard[9] and the California Cap-and-Trade Program.**[10] Prior to developing projects or programmes, users are advised to assess national GHG estimation processes and methods and any applicable regulation regarding emission rights that may limit projects' ability to generate, trade and seek payment for emission reductions and removals.[11]

**Figure 3: Potential NDC enhancement opportunities**




8 Verra. (2018). Verified Carbon Standard. *Verra*. Retrieved from https://verra.org/project/vcs-program/.

9 The Gold Standard. (2019). Retrieved from https://www.goldstandard.org/.

10 California Air Resources Board. (2019). Compliance Offset Program. Retrieved from https://www.arb.ca.gov/cc/capandtrade/offsets/offsets.htm.

11 Lee, D.L., Llopis, P., Waterworth, R.M., Roberts, G. and Pearson, T.R.H. (2018). *Approaches to REDD: nesting lessons learned from country experiences* ( No. 125270) (No. 125270; pp. 1–38). Retrieved from http://documents.worldbank.org/curated/en/670171523647847532/Main-report.

# Simplified estimation of the long-term mitigation potential of FLR

**The following section provides simplified procedures for estimating long-term net mitigation potential of FLR activities based on common principles of GHG accounting,** taking into account *carbon stocks* (such as carbon stored tree biomass and soils) and *GHG emissions* (such as $CO_2$ from fossil fuel use, $N_2O$ from fertiliser application or $CH_4$ and $N_2O$ from biomass burning) resulting from changes in land use.[12]

**To demonstrate the potential long-term mitigation benefits of FLR activities,** the guidance recommends calculating mitigation potential as the difference in ***long-term average*** *carbon stocks* (*Box 4*, below)[13] and ***lifetime GHG emissions*** between FLR and pre-FLR land uses as a simplified baseline *(Box 3)* ***across an entire portfolio of FLR activities.***

**User should note that this approach is intended to estimate the long-term mitigation potential at a high level and cannot be readily applied to national GHG accounting processes or calculation of emission reductions under REDD+ programmes that seek to quantify and report *annual* impacts.** Given the long-term nature of FLR activities and the ambition to contribute to permanent enhancement of carbon stocks, the approach is appropriate and will help raise awareness of longer-term mitigation potential of FLR. The calculation of annual mitigation potential for different FLR implementation scenarios would require users to develop additional models that should be consulted with national institutions and experts.

12 The scope of this guidance is limited to land use-related emissions including carbon stock changes in biomass and soil organic carbon, as well as $CO_2$, $N_2O$ and $CH_4$ emission related to biomass burning, fertiliser application and wetland restoration. The guidance does not cover emission related to fossil fuel use, processing or livestock emissions.

13 VCS Association. (2011). *AFOLU Guidance: Example for Calculating the Long-Term Average Carbon Stock for ARR Projects with Harvesting.* Retrieved from https://verra.org/wp-content/uploads/2018/03/VCS-Guidance-Harvesting-Examples_0.pdf.

**Box 2: Defining activity data and emission factors**

Per IPCC Guidelines the most common approach to calculate emissions is to combine the extent to which activities take place (activity data) with coefficients which quantify the emission or removals per unit activity (emission factors):

***Emissions = activity data * emission factor***

**Activity data:**

In the case of land use, the commonly used activity data is the area in hectares (ha) on which an activity takes place. It is therefore crucial to define the FLR activity in term of hectares (see *Step 1.2*).

**Emission and removal factors:**

Refers to the amount of emissions or removals of a certain GHG per hectare over a certain period (typically per year) as a result of a certain land use practice or land use change. The selection of reliable emission and removal factors is crucial to ensure robustness of emission estimates.

**Long-term mitigation potential =** $A_{FLR} * ((C_{FLR} - C_{Pre\text{-}FLR}) + (GHG_{Pre\text{-}FLR} - GHG_{FLR}))$

**Long-term mitigation potential =** *Potential emission reductions and removals ($tCO_2e$)*

$A_{FLR}$ = *Area of the proposed FLR activity (ha)*

$C_{FLR}$ = *Long-term average carbon stock per hectare of proposed FLR land use ($tCO_2e/ha$)*

$C_{Pre\text{-}FLR}$ = *Long-term average carbon stock per hectare of pre-FLR land use ($tCO_2e/ha$)*

$GHG_{FLR}$ = *GHG Emissions per hectare from FLR land use over the lifetime of the FLR activity ($tCO_2e/ha$)*

$GHG_{Pre\text{-}FLR}$ = *GHG Emissions per hectare from pre-FLR land use over the lifetime of the FLR activity ($tCO_2e/ha$)*

**Box 3: Lifetime of FLR activities (temporal scope)**

Given the ambition of FLR activities to deliver long-term and permanent emission reductions and removals, this guidance recommends calculating ER over a period of at least 30 years. FLR activities expected to be maintained over a shorter lifetime may not result in permanent emission reductions and removals. Long-term average carbon stocks and lifetime GHG emissions may be calculated for longer periods.

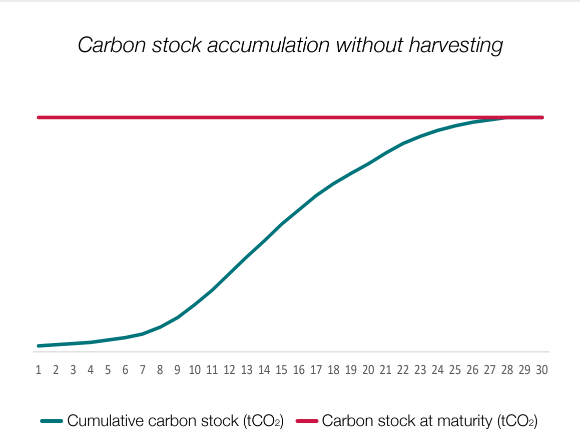
**Box 4: Calculation of long-term average carbon stocks**

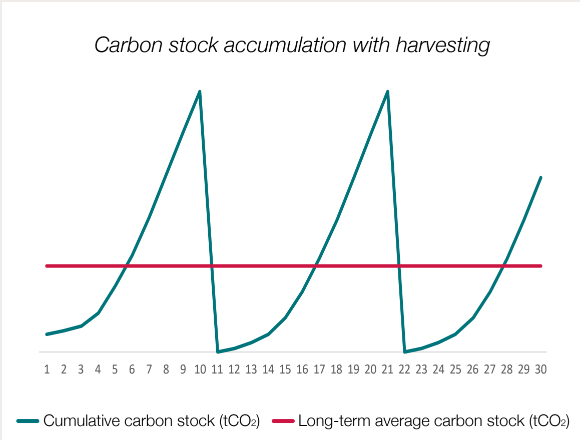
Calculations used in this guidance rely on comparing long-term average carbon stocks for each land use category rather than calculating annual fluxes (gains and losses).

For FLR land use categories that are expected to produce permanent restoration outcomes **without biomass harvesting** in rotation cycles (e.g. assisted natural regeneration, watershed protection and erosion control and mangrove restoration), it is appropriate to use **total carbon stock expected to be reached at maturity** (e.g. total carbon stock in a fully restored mangrove forest).

For FLR land use categories that involve **harvesting or rotation cycles** (e.g. planted forests and woodlots, silviculture, certain agroforestry systems, and improved fallow) which result in the total carbon stock at maturity not being maintained, it is recommended to calculate the **long-term average carbon stock over several individual harvest or rotation cycles**. To calculate the long-term average, information on annual growth rates and total rotation length are required. Similar calculation may have to be performed for pre-FLR land uses that involve harvesting and plantation cycles.

See the tables in *Worksheet 2* and the graphs below for illustrations of long-term average carbon stocks in without-harvest and with-harvest scenarios.




**The following section provides a series of *Steps* to gather data for mitigation potential estimation (*Figure 4*).** This includes a clear definition of the scope of proposed FLR activity, associated land cover changes from pre-FLR to FLR land use, geographical scope, management practices, applicable carbon pools, GHG gases and time frames. Subsequently, the geographic area on which FLR activities are proposed to take place, carbon stocks and GHG emission factors are defined before calculating total mitigation potential for the lifetime of FLR activities.

**Figure 4: Recommended steps to FLR estimate mitigation potential**

STEP 1

**Define FLR activities and pre-FLR land use**

1.1 – Clearly define FLR activity including FLR and pre-FLR land use, and associated land management regimes
1.2 – Define FLR area by pre-FLR land use
1.3 – Define temporal scope

STEP 2

**Determine changes in carbon stocks and GHG emissions**

2.1 – Select carbon pools and GHG emissions sources
2.2 – Select carbon stock values and GHG emissions factors
2.3 – Determine carbon pool and emission source significance

STEP 3

**Perform mitigation potential calculations**

3.1 – Insert information from Steps 1 & 2 in *Worksheet 4*

# STEP 1 Define type and scope of FLR activities

## 1.1 Define FLR activities and pre-FLR land use

**As a first step the proposed FLR activities for which mitigation potential is to be estimated must be clearly defined.** This is a crucial exercise to ensure the subsequent steps can be carried out effectively.

Each FLR activity implies a targeted **FLR land use** (e.g. cocoa agroforestry) that is achieved after successful implementation as well as a **pre-FLR land use** (e.g. cattle ranching) that was present before the start of the FLR activity. If a specific FLR land use is proposed on different types of pre-FLR land uses (e.g. cocoa agroforestry on ranch land vs. cocoa agroforestry on degraded forest land), this constitutes two different types of FLR Activities and *Worksheet 1* should be populated accordingly. Clear definition of FLR activity and pre-FLR land uses is an important precursor for *Step 1.2* where the area of each FLR activity is identified.

Each activity should then be **described in detail**, including the specific land management practices such as soil modifications, fertiliser applications and fire management practices. Each of these choices is important for the subsequent selection of carbon pools and emission sources. It is recommended to list separate FLR activities if different management regimes are expected, as these may lead to distinct mitigation potential estimates (e.g.

mixed species plantations vs. single species plantations). Generic definitions and grouping of FLR activities (e.g. using a single FLR activity for a range of reforestation activities) may reduce the accuracy of mitigation potential estimates and may present a challenge to selecting appropriate carbon pools and representative emission and removal factors in *Step 2*.

Finally, properly identifying the ecological zone of the FLR activity will be important for choosing emission and removal factors in *Step 2*. While the first choice for these factors should be to align with those used in national and sub-national GHG accounting, there will likely be gaps in the available data. In that case, default factors should be chosen from regional and/or global data such as the IPCC Guidelines (see *Step 2.2* and *Figure 2* for more information). These default factors are highly dependent on climate and soil types.

**For reference to IPCC Guidelines, it is helpful to categorise FLR activities according to the corresponding IPCC land- use category in *Reference Table 1***, which also provides an idea of the potential impact of different land-use activities in terms of mitigation potential.

**Worksheet 1: Define the FLR activities, pre-FLR land use and corresponding land-use transition categories**

| **1.a. FLR activity reference number** | **1.b. FLR activity** | **Detailed FLR activity description** | **1.c. Pre-FLR land use** (See *Reference Table 1* - IPCC starting land-use category) | **1.d. FLR land use** (IPCC final land -use category) | **IPCC land use sub-category** (IPCC land-use transition) | **1.e. Ecological zone** |
|---|---|---|---|---|---|---|
| 1 | **Conversion of degraded pasture to cocoa agroforestry** | Establish multi-strata agroforestry system with cocoa, timber and non-timber shade trees for commercial cocoa production on degraded pasture | Degraded pasture (G – Grassland) | Cocoa agroforestry (F – Forest Land) | GF (Grassland converted to Forest Land) | Tropical moist deciduous forest |
| 2 | **Restoration of degraded mangrove** | Mixed species restoration of degraded mangrove through assisted natural regeneration | Degraded wetland (W - Wetland) | Multi-species wetland (W) | WW (Wetland remaining Wetland) | Tropical moist deciduous forest |
| 3 | **Establishment of trees on degraded cropland** | Establishment of tree borders and wind breaks on commercial monoculture. Involves manual planting of trees with targeted fertilisation | Degraded cropland (C - Cropland) | Cropland 10% tree cover (C) | CC (Cropland remaining Cropland) | Subtropical humid forest |
| 4... | | | | | | |

## 1.2 Define FLR area by pre-FLR land use

**Defining the total area by FLR activity and pre-FLR land use** illustrated by *Worksheet 1.f.* is an important step to clearly specify where each land-use transition is expected to occur and **avoid double-counting of hectare areas**. As an example, the total area of proposed agroforestry activities must be clearly divided between areas where agroforestry is to be established on cropland vs. ranch land. The **sum of all hectares must not exceed the total FLR area**. The area data defined in *Worksheet 1.f.* will be used for mitigation potential calculations showcased in *Worksheet 4*.

**Worksheet 1.f.: Define FLR area by pre-FLR land use**

| 1.f. Hectare areas by FLR/pre-FLR land use | 1.c. Pre-FLR land use | | | |
|---|---|---|---|---|
| **1.d. FLR land use** (from *Worksheet 1*) | **Degraded pasture** | **Degraded wetland** | **Degraded cropland** | **...** |
| **Cocoa agroforestry** | 15,000 | – | – | |
| **Multi-species wetland** | – | 22,000 | – | |
| **Cropland 10% tree cover** | – | – | 45,000 | |
| **...** | | | | |

## 1.3 Define temporal scope

**The temporal scope of the proposed FLR activity, including potential activity start and activity lifetime (see *Box 3*) should be determined as a basis for calculating long-term carbon stocks** and calculating mitigation scenarios in *Step 3*. This should include the definition of harvesting cycles in commercial tree plantations (periodic harvesting and replanting regimes) (see *Box 4* for further detail on considering harvest periods). Definition of the expected lifetime of FLR activities is crucial, as it may significantly impact its ability to deliver long-term mitigation outcomes.

# STEP 2 Determine changes in carbon stocks and GHG emissions

## 2.1 Select carbon pools and GHG emission sources

**A core component of the mitigation potential estimation process is the selection of applicable carbon pools and sources of GHG emissions.** *Reference Table 2* provides an overview of **carbon pools** and **GHG emission sources**. As a first step, users must determine whether the management regimes of FLR and pre-FLR land uses defined in *Step 1* are likely to lead to changes in carbon stocks and GHG emissions (see examples in *Reference Table 1*) for each carbon pool. On this basis, users should make an initial decision on whether to include respective carbon pools and sources for each FLR activity from *Worksheet 1*.

**Subsequently, it is recommended to obtain information on, and align with, the carbon pools and GHG emission sources selected for national GHG estimation.** Users should discuss selection of carbon pool and GHG emissions with relevant experts. If significant carbon pools or GHG emission sources have been excluded from national GHG estimation, users may discuss the possible inclusion with national experts. Under UNFCCC reporting requirements, countries should progressively expand the number of pools and sources reported over time to eventually include all that are relevant. The FLR estimation process can help to identify these missing categories.

**Reference Table 2: Description of carbon pools and greenhouse gas emissions**

| Carbon pools | Description, subject to national circumstances and modifications |
|---|---|
| **Above-ground biomass** | All living biomass above the soil is usually expressed in tonnes of dry matter (t.d.m). This includes plant and tree stems, living stumps, branches, bark, seeds and foliage. As it is a dominant carbon pool in most forest systems, it is almost always included in carbon accounting in FLR. Values for above-ground and below-ground biomass can be estimated through direct measurement[14] or can be found in the published and unpublished literature. |
| **Below-ground biomass** | All living plant roots, usually excluding fine roots of less than 2 mm in diameter. This can be estimated without direct measurement using published "root-to-shoot" ratios, available in the IPCC Guidelines, between above-ground and below-ground biomass. In other words, if above-ground biomass is known, a factor can be applied to estimate below-ground biomass.[15] |
| **Dead wood** | All non-living woody biomass not counted as litter, standing, lying on the forest floor or in the soil. Includes dead stumps, fallen branches and dead roots larger than a certain diameter (often defined as 10 cm). In young ecosystems <30 years, biomass in dead wood are generally not considered significant.[16]<br>Where direct measurement is overly burdensome and there is a desire to include dead wood biomass, it can be estimated without direct measurement applying published factors that describe the relationship between above-ground and below-ground biomass, available in the IPCC Guidelines. |

14 Methods to quantify carbon stocks in terrestrial biomass are available from many sources, including Walker, S.M., Pearson, T.R.H., Casarim, F.M., Harris, N., Petrova, S., Grais, A. et al. (2012). *Standard Operating Procedures for Terrestrial Carbon Measurement Manual: Version 2018*. Retrieved March 13, 2019, from https://www.winrock.org/document/standard-operating-procedures-for-terrestrial-carbon-measurement-manual/.

15 Pearson, T., Harris, N., Shoch, D. and Brown, S. (2016). 'Estimation of forest carbon stocks'. In GOFC-GOLD, *A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals associated with deforestation, gains and losses of carbon stocks in forests remaining forests and forestation* (GOFC-GOLD Report version COP 22-1). Retrieved 17 September 2018 from http://www.gofcgold.wur.nl/redd/sourcebook/GOFC-GOLD_Sourcebook.pdf.

16 Pearson, T., Walker, S. and Brown, S. (2005). *Sourcebook for Land Use, Land-Use Change and Forestry Projects*. BioCF and Winrock International

### Reference Table 2: Description of carbon pools and greenhouse gas emissions *(continuation)*

| | |
|---|---|
| **Litter** | All non-living biomass less than a certain diameter (often defined as 10 cm), lying dead and decaying above the mineral or organic soil. This includes fallen leaves and small branches, as well as the fumic and humic layers of the forest floor. Fine roots less than 2 mm in diameter are usually counted as litter when they cannot be distinguished from other matter in these layers. In young ecosystems <30 years, biomass on the floor are generally not considered significant.[17]<br>Where direct measurement is overly burdensome and there is a desire to include litter biomass, it can be estimated without direct measurement applying published factors that describe the relationship between above-ground and below-ground biomass, available in the IPCC Guidelines. |
| **Soil organic carbon** | Includes the organic carbon in mineral and organic soils to a country-defined depth, applied consistently throughout the estimation process. Fine roots less than 2 mm in diameter are usually included in soil organic carbon at the defined depth. |
| **Greenhouse gases** | **Description of emission sources** |
| **Carbon dioxide ($CO_2$)** | Plants absorb $CO_2$ from the atmosphere and store some of this carbon in their tissue as they grow. Some of the carbon plants absorb is also transferred to and stored in soils. Depending on land management practices, the carbon stored in plants and soils may be released back into the atmosphere as $CO_2$ (e.g. through biomass burning and decay).<br>$CO_2$ absorption and release by plants is already considered in carbon stock changes (see carbon pools above). **An exception is the case of losses in the soil carbon pool in drained and/or degraded wetlands. Instead of estimating carbon stock changes, it is recommended to use an emission factor for annual $CO_2$ emissions occurring in drained and/or degraded wetlands as the pre-FLR land use.** In the FLR land use (e.g. restored wetland), carbon stock accumulation in the soil carbon pool can be considered but is likely insignificant in the short- to medium-term. |
| **Methane ($CH_4$)** | Wildfires and other forest disturbance can lead to a significant emission of $CH_4$ which can be included in GHG estimations. $CH_4$ will likely also be a significant source of emissions in the case of rewetting soils, such as re-establishing mangroves, due to anaerobic decomposition of organic matter.<br>Livestock is another considerable source of $CH_4$ that should be taken into account if an FLR activity leads to the introduction of livestock (e.g. conversion of cropland to silvopastoral systems) or increase in the number of animals per hectare. |
| **Nitrous oxide ($N_2O$)** | $N_2O$ and other nitrogen oxides ($NO_X$) are commonly released in the land-use sector from soils due to the application of nitrogen fertilisers and the drainage of wet forest soils. Forest management practices such as clear cutting and thinning may also increase $N_2O$ emissions. |

*Carbon pool descriptions adapted from Table 3.1.2 of the 2006 IPCC Good Practice Guidance for LULUCF and Volume 4, Chapter 12 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Greenhouse gas emission sources adapted from the U.S. Environmental Protection Agency website and the 2006 IPCC Good Practice Guidance for LULUCF.*

***Box 5* provides an overview of key principles for mitigation estimation. Taken together, these principles aim to provide an accurate picture of the scale of mitigation expected without overstating benefits or expending undue effort in the estimation process.**

**In accordance with the IPCC principle of completeness, it is considered best practice to include carbon pools and emission sources if significant changes are expected as a result of the FLR land use relative to the pre-FLR land use** (e.g. there would be a significant change in above ground and below ground biomass due to the afforestation of cropland). Where carbon pool and GHG emission source significance is not immediately obvious, users must first identify carbon stock and GHG emission data as described (in *Step 2.2*) and determine significance relative to total stocks and emissions (*Step 2.3*). Final carbon pool and GHG emission source selection may therefore be an iterative process.

**Users should apply the conservativeness principle throughout the process.** Where determination of carbon stocks or GHG emissions would be associated with unreasonable effort, carbon pools and GHG emission sources may be excluded subject to the application of the conservativeness principle.

17 Pearson, T. et al. (2005).

**Box 5: Key principles for mitigation estimation**

### Completeness

To meet the principle of completeness, all relevant sources and sinks and all relevant gases should be considered in the estimation process, covering the full geographic area where FLR activities are implemented. Sources, sinks and gases may be excluded subject to the application of the Significance and Conservativeness principles.

### Significance

Significance is the level of contribution of a source, sink or gas to the total change in emissions or removals (e.g. an increase in $CH_4$ might contribute 2% of the total emission increase for a certain project). Existing standards apply different significance thresholds to determine whether a certain source, sink or gas may be excluded. For example, the FCPF Carbon Fund Methodological Framework specifies that carbon pools and gases may be excluded if they are collectively estimated to contribute to less than 10% of total forest-related emissions, whereas the Clean Development Mechanism applies a threshold of 5%.[18]

### Conservativeness

The principle of conservativeness specifies that when estimating greenhouse gas emissions reductions and removals, the risk of overestimation of emission reductions and removals should be minimised. It is considered conservative to (i) overestimate carbon stocks or underestimate GHG emissions in the pre-FLR land use or (ii) underestimate carbon stocks or overestimate GHG emissions in the FLR activity.

### Uncertainty

Given the complexities of natural ecosystems, the estimation of ER can be associated with significant degrees of uncertainty. Uncertainty should be reduced wherever possible through selection of reliable data and estimation approaches. IPCC Guidelines provide methods for analyzing uncertainty.

18 FCPF. (2016). *FCPF Carbon Fund Methodological Framework (Revised Final)*. Retrieved 20 January 2019, from https://www.forestcarbonpartnership.org/sites/fcp/files/2016/July/FCPF%20Carbon%20Fund%20Methodological%20Framework%20revised%202016.pdf; CDM - Executive Board. (2007). *Tool for testing significance of GHG emissions in A/R CDM project activities (Version 01)* (No. EB 31 annex 16) (No. EB 31 annex 16). Retrieved from https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-04-v1.pdf.

## 2.2 Select carbon stock values and GHG emission factors

**ER estimations under this guidance require users to determine the following for both the FLR activity and the pre-FLR land use:**

1. **Long-term average carbon stock** across all select pools for each land use category (*Worksheet 3*, column 3.g.) – please see *Box 4* and *Worksheet 2, part 1* for guidance on calculating long-term averages for each selected carbon pool

2. **Lifetime GHG emissions** from each land use category (*Worksheet 3*, column 3.k.) – calculated as the average annual GHG emissions multiplied by the lifetime of the FLR activity. Please see *Worksheet 2, part 2* for guidance on calculating lifetime GHG emissions for each gas.

**The determination of both long-term average carbon stocks and lifetime GHG emissions may require separate calculations, taking into account annual carbon stock changes and GHG emissions over the lifetime of FLR activities.** Accuracy in mitigation benefit estimation for FLR activities relies on how well the selected carbon stocks for FLR activities reflect the climate, landscape characteristics, tree species and management practices of the FLR activity of interest.

Removal factors describe the rate at which different types of FLR remove $CO_2$ from the atmosphere. Emissions factors, meanwhile, refer to the amount of a gas released into the atmosphere due to an FLR activity. Information on these factors should ideally be attained through conversations with national GHG accountants and/or landscape programme administrators and from country submissions to the UNFCCC (see *Box 1*). Where data gaps exist, it is best practice to rely on values from regional or country-specific scientific and peer-reviewed literature. The Global FLR $CO_2$ Removals Database[19] provides regionally specific default removal factors for four FLR activity categories[20] based on a broad review of tree growth studies. Finally, when more specific data is not available, estimations may be made using applicable default factors, recognising that these may not match the desired granularity of FLR activities previously defined. Default factors for land-use transitions may be found in the latest IPCC Guidelines.

19 Available at https://infoflr.org/what-flr/global-emissions-and-removals-databases. More information on this database, including values for uncertainty is available in Bernal, B., Murray, L.T. and Pearson, T.R. (2018). Global carbon dioxide removal rates from forest landscape restoration activities. *Carbon Balance and Management* 13:22. https://cbmjournal.biomedcentral.com/articles/10.1186/s13021-018-0110-8

20 Planted forests and woodlots, natural regeneration, agroforestry and mangrove restoration

### Worksheet 2, part 1: Sample calculation of long-term average carbon stocks, with and without harvest cycles[21]

| Carbon stock without harvest cycle | | Carbon stock with 10-year harvest rotation | |
|---|---|---|---|
| Year | Cumulative carbon stock ($tCO_2$) | Year | Cumulative carbon stock ($tCO_2$) |
| 1 | 6.00 | 1 | 6.00 |
| 2 | 13.00 | 2 | 13.00 |
| 3 | 19.00 | 3 | 19.00 |
| 4 | 25.00 | 4 | 25.00 |
| 5 | 32.00 | 5 | 32.00 |
| 6 | 42.00 | 6 | 42.00 |
| 7 | 54.00 | 7 | 54.00 |
| 8 | 62.00 | 8 | 62.00 |
| 9 | 78.00 | 9 | 78.00 |
| 10 | 90.00 | 10 | 90.00 |
| 11 | 102.00 | 11 | - |
| 12 | 116.00 | 12 | 6.00 |
| 13 | 122.00 | 13 | 13.00 |
| 14 | 130.00 | 14 | 19.00 |
| 15 | 140.00 | 15 | 25.00 |
| 16 | 148.00 | 16 | 32.00 |
| 17 | 159.00 | 17 | 42.00 |
| 18 | 164.00 | 18 | 54.00 |
| 19 | 172.00 | 19 | 62.00 |
| 20 | 180.00 | 20 | 78.00 |
| 21 | 192.00 | 21 | 90.00 |
| 22 | 200.82 | 22 | - |
| 23 | 208.00 | 23 | 6.00 |
| 24 | 219.00 | 24 | 13.00 |
| 25 | 225.00 | 25 | 19.00 |
| 26 | 236.00 | 26 | 25.00 |
| 27 | 241.00 | 27 | 32.00 |
| 28 | 242.00 | 28 | 42.00 |
| 29 | 242.50 | 29 | 54.00 |
| 30 | 242.50 | 30 | 62.00 |
| **Long-term average carbon stock ($tCO_2$)** | Carbon stock at maturity **242.50** | **Long-term average carbon stock ($tCO_2$)** | Average of years 1-30: **36.50** |

21 VCS Association. (2011).

### Worksheet 2, part 2: Sample calculation of lifetime greenhouse gas emissions, using annual GHG emissions factor

| Lifetime GHG Emissions | |
|---|---|
| **Annual GHG emissions ($tCO_2e/ha/yr$)** (e.g. methane ($CH_4$)) | **2.23** |
| **Year** | **Cumulative GHG emissions ($tCO_2e$)** |
| 1 | 2.23 |
| 2 | 4.46 |
| 3 | 6.69 |
| 4 | 8.92 |
| 5 | 11.15 |
| 6 | 13.38 |
| 7 | 15.61 |
| 8 | 17.84 |
| 9 | 20.07 |
| 10 | 22.30 |
| 11 | 24.53 |
| 12 | 26.76 |
| 13 | 28.99 |
| 14 | 31.22 |
| 15 | 33.45 |
| 16 | 35.68 |
| 17 | 37.91 |
| 18 | 40.14 |
| 19 | 42.37 |
| 20 | 44.60 |
| 21 | 46.83 |
| 22 | 49.06 |
| 23 | 51.29 |
| 24 | 53.52 |
| 25 | 55.75 |
| 26 | 57.98 |
| 27 | 60.21 |
| 28 | 62.44 |
| 29 | 64.67 |
| 30 | 66.90 |
| **Lifetime GHG emissions ($tCO_2e$)** | **66.90** |

**Once calculated, long-term average carbon stocks by pool and lifetime GHG emissions by source are inserted in *Worksheet 3*. When selecting carbon stock values and GHG emission factors for calculations, applicable units must be carefully considered.** Given the use of a variety of units in country submissions, emission reduction programmes, projects and scientific literature, it may be required to convert values to the units required in *Worksheet 3*. The following questions should be considered in the process of determining values from selected information sources:

- Are the carbon stocks selected **representative of the expected management regime** including harvesting cycles (e.g. a forestry plantation may contain a certain carbon stock at its peak but the *average* carbon stored over each harvesting cycle will be less – see *Box 4*)?
- Is the emission factor for a land-use category expressed as a **per hectare value**? If not, can a per hectare value be determined based on the total area in question? If not, a per hectare value must be identified from other sources per *Figure 2*.
- Is the emission factor a **gross or net value**? It is preferable to determine gross values for each land- use category. [22]
- Is the carbon stock expressed in **metric tonnes (t)**? If not, it must be converted to tonnes.
- Are biomass values provided in **tonnes of dry matter (t.d.m.)**? If so, first convert to tonnes of carbon (tC = t.d.m * 0.47) and then to $tCO_2$ multiplying the tC value by 3.67 (or 44/12).
- Is the carbon stock expressed as **tC or $tCO_2$**? If expressed as tC it must be converted to $tCO_2$, multiplying the tC value by 3.67 (or 44/12).
- Are $CH_4$ and $N_2O$ emissions expressed as **tonnes of $CO_2$ equivalent ($tCO_2e$)**? If not, $CH_4$ and $N_2O$ value must be converted to $tCO_2e$ using warming potential conversion factors.[23]
- Are GHG emissions expressed as an **average annual value ($tCO_2e/yr$)**? If not, an average annual value must be calculated and multiplied by the lifetime of the FLR activity to determine lifetime emissions (*Worksheet 2, part 2*).

22 If gross values cannot be found, columns 4.b. and 4.e. in *Worksheet 4* need to be set to zero (0).

23 Greenhouse Gas Protocol. (2016). *Global Warming Potential Values.* Retrieved from https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf.

## Worksheet 3: Long-term average carbon stocks and lifetime GHG emissions by land-use category

| 1.b. FLR land use | 1.e. Ecological zone | 3.a. Sources and figures | Long-term average carbon stocks by pool ($tCO_2$/ha) | | | | | | Lifetime emissions by gas ($tCO_2e$/ha) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **3.b. Above-ground biomass** | **3.c. Below-ground biomass** | **3.d. Dead wood** | **3.e. Litter** | **3.f. Soil organic carbon** | **3.g.** =3.b. + 3.c. + 3.d. + 3.e. **Total carbon stock** | **3.h. $CO_2$** (*see note) | **3.i. $CH_4$** | **3.j. $N_2O$** | **3.k.** = 3.h. + 3.i. + 3.j. **Total Lifetime GHG emissions** |
| Cocoa agroforestry | Tropical moist deciduous forest | 3.b. Value of 17.04 tC above-ground biomass for mature cocoa stand drawn from local study of agroforestry-type mentioned in country NDC. Converted to $tCO_2$ as $CO_2$ = C * (44/12)<br>3.c. Below-ground biomass for agroforestry systems is excluded in country's national inventory report. However, it is included here after discussion with national GHG accountants due to expected significance of the pool. Calculated from 3.b. based on root-to-shoot ratio of 0.20 for cocoa.<br>3.j. Value of 0.0017 $tN_2O$/ha/yr drawn from scientific study of similar agroforestry system and ecological zone. Multiplied by 265 GWP to get $tCO_2e$ and multiplied by 30 years. | 62.47 | 12.49 | - | - | - | **74.96** | - | - | 13.80 | **13.80** |
| Multi-species wetland | Tropical moist deciduous forest | Tier 1 values for tropical mangroves draw from IPCC Tier 1 values for tropical mangroves draw from IPCC 2013 Wetlands Supplement, chapter 4, conservatively selected "dry" vs. "wet" for tropical moist zone.<br>3.b. 92 tonnes dry matter/ha for Tropical Dry mangroves. Converted to tC with default factor of 0.47. Then converted to $tCO_2$ = C * (44/12)<br>3.c Calculated from 3.b with a root-to-shoot ratio of 0.29 in Tropical dry mangroves.<br>3.d. Tier 1 value of 10.7 tC/ha dead wood of mature mangrove stands, converted as $tCO_2$ = C * (44/12)<br>3.e. Litter excluded for insignificance<br>3.f. Soil organic carbon excluded for conservativeness; assumed to be similar to pre-FLR levels<br>3.i Rewetting emission factor for $CH_4$ in Tidal brackish mangrove, 0.1937 $tCH_4$/ha/yr. Converted to $tCO_2e$ with 25 GWP and multiplied by 30 years. | 158.55 | 45.98 | 39.23 | - | - | **243.76** | - | 145.28 | - | **145.28** |
| Cropland 10% tree cover | Subtropical humid forest | Conservatively excluding carbon stock increase from non-tree biomass increase.<br>3.b. Above-ground biomass for 10% tree cover drawn from local study of trees on cropland, used in national GHG accounting. Value = 5.00 tC/ha. Converted to $tCO_2$ = C * (44/12)<br>3.c. Calculated from 3.b. with a subtropical humid forest root-to-shoot ratio of 0.20, based on Tier 1 value of IPCC 2006 Guidelines, for Subtropical humid forest ecological zone.<br>3.j. $N_2O$ emissions from management assumed to be the same as pre-FLR use. After calculation of fertiliser-based $N_2O$ emissions, significance is less than 1% and therefore excluded. | 18.33 | 3.67 | - | - | - | **22.00** | - | - | - | **-** |

### Worksheet 3: Long-term average carbon stocks and lifetime GHG emissions by land-use category *(continuation)*

| 1.d. Pre-FLR land use | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Degraded pasture | Tropical moist deciduous forest | 3.b. Above-ground biomass value of 12.44 tonnes d.m./ha based on local study of degraded grassland. Converted to tC with default factor of 0.47, then converted as $tCO_2 = C * (44/12)$<br>3.c. Below-ground biomass calculated from 3.b. using root-to-shoot ratio of 1.8, empirically-derived from same local study.<br>3.h.-j. excluded due to insignificance and for conservativeness | 21.43 | 38.57 | - | - | - | **60.00** | - | - | - | **-** |
| Degraded wetland | Tropical moist deciduous forest | Tier 1 values based on IPCC 2013 Wetlands supplement<br>3.b. Value of 92 tonnes d.m./ha for Tropical dry mangroves, multiplied by a 0.70 conversion factor for degradation. Converted to tC with default factor of 0.47, then converted as $tCO_2 = C * (44/12)$<br>3.c. Calculated based on 3.b. with a root-to-shoot ratio of 0.29<br>3.d. Dead wood excluded due to assumption of degradation due to fuelwood collection.<br>3.h. Annual emission factor for $CO_2$ associated with soil drainage of 7.9 tC/ha/yr. Converted to $tCO_2 = C * (44/12)$ and multiplied by 30 years. | 110.98 | 32.18 | - | - | - | **143.17** | 869.00 | - | - | **869.00** |
| Degraded cropland | Subtropical humid forest | 3.b. Above-ground biomass value of 2.34 tC/ha for cropland without tree cover, based on local study used in national GHG accounting. Converted to $tCO_2 = C * (44/12)$.<br>3.h-3.j Excluded due to significance/conservativeness | 8.58 | - | - | - | - | **8.58** | - | - | - | **-** |

**Lifetime emissions of $CO_2$ should only be separately accounted for in the case of soil oxidation in drained wetlands, since otherwise $CO_2$ change is accounted for in the carbon pools. See Reference Table 2 for more information.*

## 2.3 Determine carbon pools and GHG emission source significance

**A variety of thresholds have been applied at national, sub-national and project level to determine significance of carbon pools and emission sources.** As with previous steps, it is recommended that users identify approaches and thresholds applied at the national level as a starting point. See *Box 5* for more information on choosing and applying a significance threshold.

**User should identify a significance threshold according to the intended use of estimation result at the beginning of the estimation process and stick with the identified threshold throughout the estimation process.** In other words, users should not raise or lower the significance threshold partway through the estimation process or apply different threshold for different FLR activities.

As mentioned in *Step 2.1*, determining the significance of carbon pools and GHG emission sources may be an iterative process. The user may need to perform calculations in *Worksheet 3* for a certain selection of pools and sources in order to determine the percentage of a given pool or source relative to the total across all pools and sources. At that point, a decision can be taken with regards to inclusion or exclusion of a given pool or source from subsequent calculations.

**In line with the conservativeness principle** (see *Box 5*)**, users should not purposefully exclude carbon pools that are expected to decrease (and GHG emission sources that are likely to increase) as a result of the FLR land use relative to the pre-FLR land use as such exclusion would lead to an overestimation of the mitigation potential of the FLR activity.**

# STEP 3 Calculate mitigation potential

Estimate to the total mitigation potential across all FLR activities and implementation areas identified, *Worksheet 4* must be populated with data generated in *Worksheets 1, 2 and 3*. This includes:

1. FLR activity and pre-FLR land use combinations from *Worksheet 1*
2. Hectare figures for each FLR activity and pre-FLR land use combination based on *Worksheet 1.f*.
3. Lifetime (in years) of each FLR activity
4. Long-term average carbon stocks and lifetime GHG emissions for each FLR activity and pre-FLR land use determined in *Worksheets 2 and 3*

## Worksheet 4: Mitigation potential calculations

| 1.a. FLR activity category # | 1.b. FLR activity | (t) Time period (years) | 1.f. Hectare potential | 4.a. (from 3.g.) Carbon stocks per FLR land use ($tCO_2/ha$) | 4.b. (from 3.g.) Carbon stocks per pre-FLR land use ($tCO_2/ha$) | 4.c. = 4.a. - 4.b. Net carbon stock change from FLR Activity ($tCO_2/ha$) | 4.d. (from 3.k.) Emissions per FLR land use ($tCO_2e/ha$) | 4.e. (from 3.k.) Emissions per pre-FLR land use ($tCO_2e/ha$) | 4.f. = 4.e. - 4.d. Net emission change from FLR Activity ($tCO_2e/ha$) | 4.g. = 4.c.+4.f. Potential net mitigation from FLR activity from FLR activity ($tCO_2e$ / ha) | 4.h. = 4.g. * 1.f. Total potential net mitigation from FLR activity ($tCO_2e$) | 4.i. = 4.h. / (t) Total potential net mitigation from FLR activity per year ($tCO_2e$/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | **Conversion of degraded pasture to cocoa agroforestry** | 30 | 15,000 | 74.96 | 60.00 | 14.96 | 13.80 | - | (13.80) | 1.16 | 17,400 | 580 |
| **2** | **Restoration of degraded mangrove** | 30 | 22,000 | 243.76 | 143.17 | 100.59 | 145.28 | 869.00 | 723.72 | 824.31 | 18,134,766 | 604,492 |
| **3** | **Establishment of trees on cropland** | 30 | 45,000 | 22.00 | 8.58 | 13.42 | - | - | - | 13.42 | 603,900 | 20,130 |
| **Total** | | | **82,000** | | | | | | | | **18,756,066** | **625,202** |

**Note that the result in *Worksheet 4* shows the total mitigation potential for the entire portfolio of FLR activities if implemented over the entire area and maintained over the entire lifetime (see *Box 3*).** While the calculation helps to demonstrate the total mitigation potential to policy makers and other stakeholders, it is important to remember that these mitigation **results are not achieved immediately but accrue over time**. Carbon stocks accumulate in the landscape incrementally and unevenly over time as FLR activities are implemented.

To assess the long-term mitigation potential of short-term implementation scenarios (e.g. mangrove restoration initially on only 5,000 ha as opposed to the total restoration potential of 22,000 ha), hectare figures can be adjusted.

The calculation of mitigation potential to be achieved by a given date (e.g. 2030) would require both the definition of annual implementation targets (annual hectares for each FLR activity) and the calculation of annual carbon stock changes and GHG emissions. This may require the development of more sophisticated models and should be developed in consultation with national institutions and experts.

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