THE CLIMATE FOOTPRINT PROJECT

TRACKING EMISSIONS / RAISING AMBITION

UNDER2° Secretariat CLIMATE GROUP

Demystifying GHG emissions and removals from the AFOLU sector for states and regions

This document was prepared by Marcelo Theoto Rocha, Flavia Carloni, Sabina Shaikh and Chris Thorpe at Ricardo Energy & Environment as part of the Climate Footprint Project | June 2021

About the Climate Footprint Project

The Climate Footprint Project supports state and regional governments to improve their greenhouse gas emissions tracking and reduction efforts. In the first phase of the project, the project worked with states and regions in developing and newly industrialising countries including Pernambuco (Brazil), Chhattisgarh and West Bengal (India), Baja California, Jalisco and Yucatán (Mexico), and KwaZulu-Natal (South Africa).

Overview

This technical knowledge product is designed to support states and regions (further referred to as ´regions´) in understanding greenhouse gas (GHG) emissions and removals from the Agriculture, Forestry and Other Land Use (AFOLU) sector.

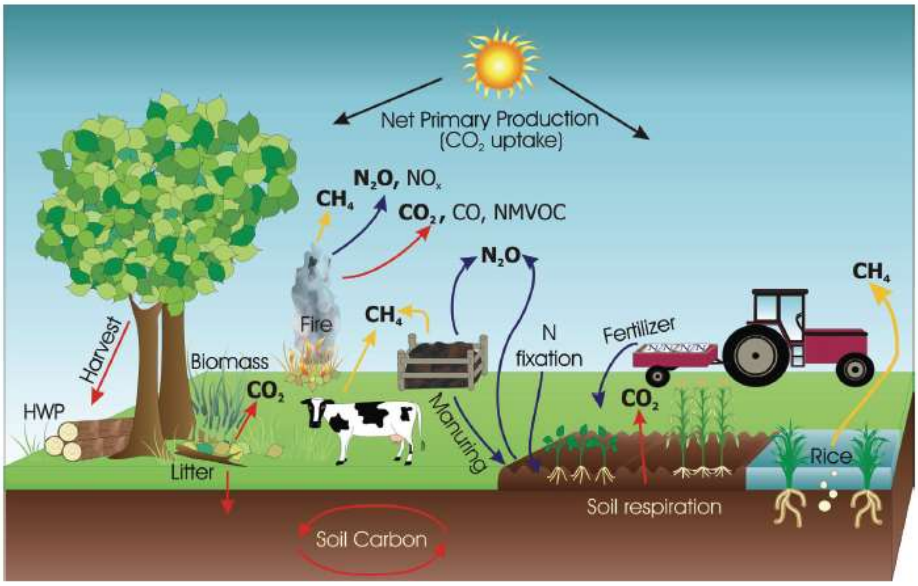
It explores the relation of the AFOLU sector to GHG emissions and removals and how these GHG emissions and removals can be estimated using the 2006 Intergovernmental Panel on Climate Change Guidelines (2006 IPCC Guidelines). It also delves into how these emissions and removals can be disaggregated from the national GHG inventory. Finally, it details the ways in which these estimates can feed into the monitoring, reporting and verification (MRV) of climate change polices and measures related to the AFOLU sector.

What is the relation of the AFOLU sector to GHG emissions and removals?

AFOLU stands for Agriculture, Forestry and Other Land. According to the IPCC, this sector accounts for around 23% of global GHG emissions.[1] The main sources of GHG emissions and removals in the sector are illustrated in **Figure 1**. This image is taken from the 2006 IPCC Guidelines and while simplified, the coloured arrows depict how the various GHGs in the AFOLU sector interact within our ecosystems.

The diagram includes several abbreviations (HWP and NMVOC) beyond the GHG abbreviations listed below the figure. HWP stands for "Harvested Wood Products", such as pulp and paper, wood pellets, and construction lumber amongst others. And NMVOC stands for Non-Methane Volatile Organic Compounds, which includes organic compounds such as benzene, ethanol, formaldehyde, typically released during combustion processes.

Figure 1: The main GHG emissions processes in managed ecosystems[2]



GHG abbreviations: CO – Carbon Monoxide / **CO_2** – Carbon Dioxide / **CH_4** – Methane / **N_2O** – Nitrous Oxide / **NO_x** – Nitrogen Oxides

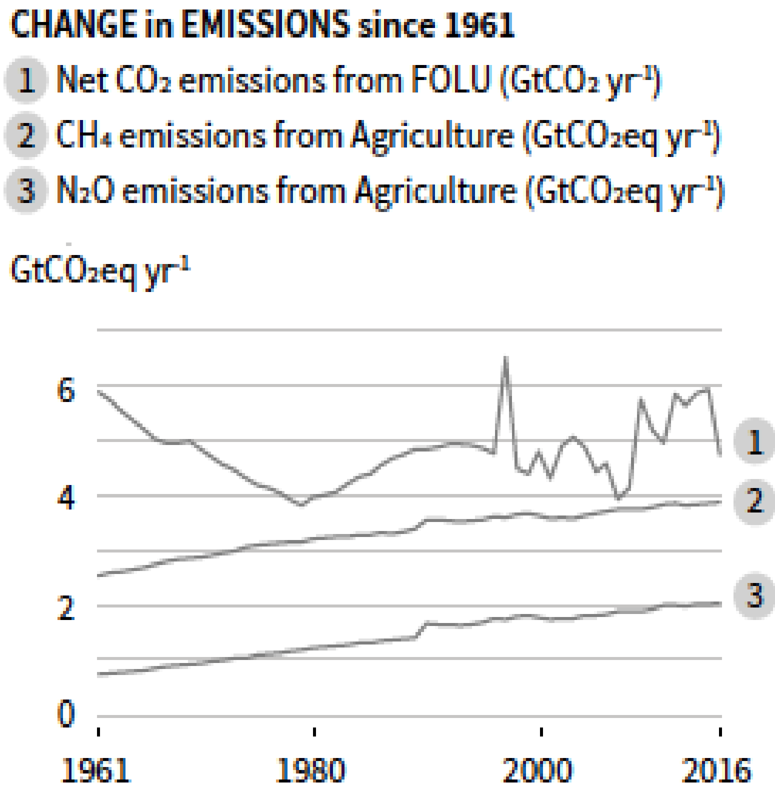
[1] Source: IPCC, 2019: Summary for Policymakers. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.- O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press. Available at: https://www.ipcc.ch/srccl/

[2] Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Volume 4: Agriculture, Forestry and Other Land Use - Chapter 1: Introduction. Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_01_Ch1_Introduction.pdf

Unlike other GHG inventory sectors, the AFOLU sector accounts for GHG sinks, as well as sources. For instance, a source of GHG emissions in the AFOLU sector is the emission of CH_4 from the enteric fermentation process in herbivore livestock, illustrated by a cow in the above diagram. Similarly, removals of GHG emissions occur during the process of photosynthesis in plants such as trees, where CO_2 is absorbed and O_2 is created. The difference between these emissions and removals (i.e. emissions minus removals) results in the use of the term “net” emissions.

As can be observed in **Figure 2**, net CO_2 emissions from forestry and other land use have varied significantly over time. This includes high interannual fluctuations, most likely a consequence of changes in land use, particularly changes in deforestation rates in developing countries. CH_4 and N_2O emissions from agriculture, on the other hand, have maintained a steady increase.

Figure 2: Change in AFOLU sector GHG emissions since 1961 [1]



For the purposes of estimating and reporting GHG emissions and removals under the United Nations Framework Convention on Climate Change (UNFCCC), national governments follow the 2006 IPCC

Guidelines[3], where the methodologies and approaches to estimate GHG emissions and removals from AFOLU are described in Volume 4[4]. While the Guidelines present these methodologies or approaches in a single volume, these GHG emissions and removals estimates are reported by national governments to the UNFCCC under two different sectors, referred to as "Agriculture" and "Land Use, Land-Use Change and Forestry" (LULUCF).

In this knowledge product, the term "AFOLU" will be used for the purposes of presenting and explaining the main methodologies of the 2006 IPCC Guidelines. When referring to reporting requirements under the UNFCCC however, "Agriculture" and "LULUCF" sectors will be mentioned.

Each country and region will have different AFOLU GHG emissions and removals, that vary in the significance of their contribution, and therefore influence the development of mitigation policies and measures. The correct identification of these sources and sinks is critical to ensuring the most efficient use of human, technological and financial resources when estimating AFOLU GHG emissions and removals. The next section will therefore present recommendations for the correct identification of the most relevant sources of AFOLU GHG emissions and removals.

The 4-step decision tree for regional AFOLU GHG inventories

To estimate AFOLU GHG emissions and removals at the regional level, a simplified 4-step decision tree has been developed. These 4-steps are as follows:

1. **Identify key categories –** Identify the key AFOLU sources (also known as categories) that contribute the most to total GHG emissions and removals.
2. **National-regional estimates –** Check if the national GHG inventory already presents estimates of the sources/categories identified within the region, i.e. disaggregated estimates.
3. **Determine disaggregation criteria –** Agree on criteria and/or assumptions to disaggregate the national GHG estimates.
4. **Estimation of remainder –** Estimate, using the 2006 IPCC Guidelines, the GHG emissions/removals only for remaining categories not covered by steps 2-3.

For **Step 1**, regions need to identify the key categories of GHG emissions and removals, as split between Agriculture and LULUCF. They can do this by familiarising themselves with the list of key sources/categories available in **Appendix 1.**

For **Step 2,** regions should check if the national GHG inventory already presents estimates of the categories at the regional level. If national estimates are disaggregated to this level, there is no need to

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[3] IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan. Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

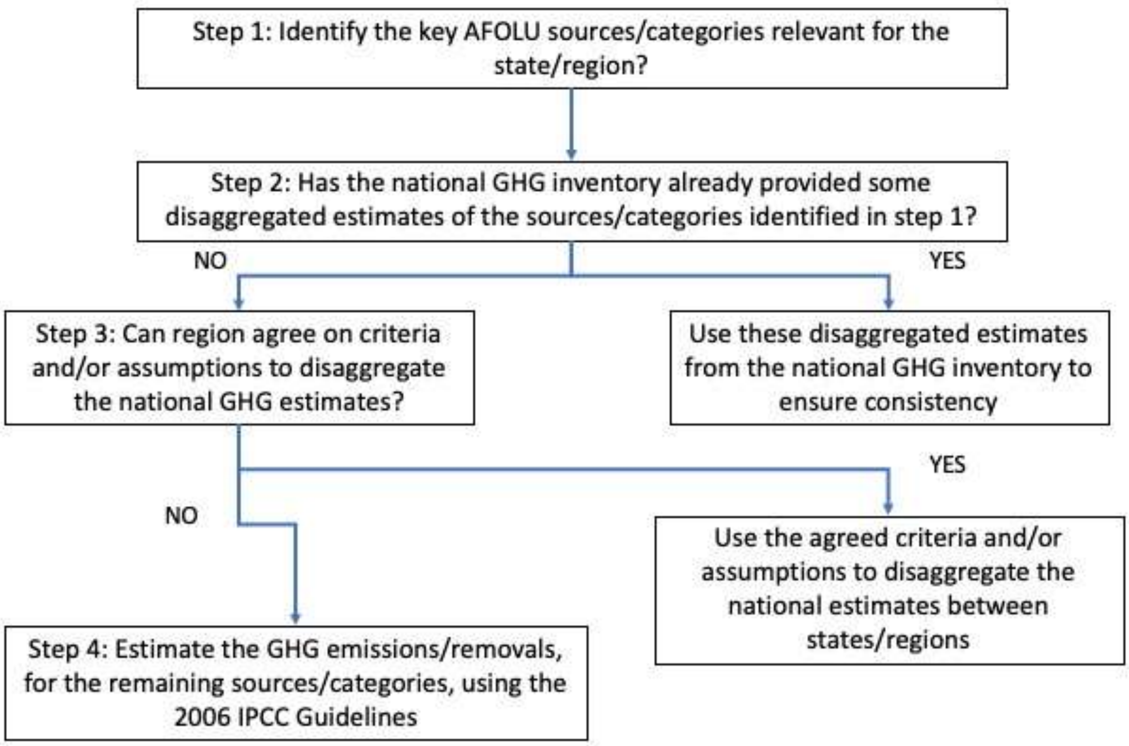
[4] Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

estimate GHG emissions and removals again. The use of the disaggregated national estimates will ensure consistency between national and regional inventory reports, as well as in the development and implementation of mitigation policies and measures.

For **Step 3**, regions should agree on the criteria and/or assumptions to be made in order to disaggregate the national GHG estimates. National estimates can be disaggregated to the regional level using different criteria and/or assumptions, for example using proportional distribution of national GHG emissions and removals based on selected indicators (e.g. agricultural production statistics per region; aggregated value of agricultural production per region; land use areas per region, etc). Once the most appropriate criteria, assumptions and indicators are defined, the national estimate can be disaggregated to the regional level thorough the use of the chosen parameters.

For **Step 4,** regions should estimate, using the 2006 IPCC Guidelines, the GHG emissions and removals only for those remaining categories that were not presented at a disaggregated regional level or that could not be disaggregated using agreed criteria or assumptions.

Figure 3: Decision tree diagram



The importance of high-quality activity data

Having familiarised yourself with what the AFOLU sector is, and how to use a 4-step decision tree to start estimating regional level emissions and removals, the next consideration to underline is the importance of high-quality activity data. According to the IPCC (2006)[5], the most simple methodological approach for calculating emissions and removals is to multiply information on the extent to which a human activity takes place (called activity data or AD) with coefficients which quantify the emissions or removals per unit activity (called emission factors or EF). The basic equation for this is as follows:

$$\boldsymbol{Emissions = AD * EF}$$

Therefore, to ensure that AFOLU GHG emissions and removals at the regional level are as accurate as possible, it is critical to use the most appropriate and reliable AD and EF. Within this technical knowledge product, whilst it isn't possible to present all of the data requirements to estimate GHG emissions and removals in all AFOLU categories, there are two common sets of AD that are used across several AFOLU GHG categories, and that may differ significantly between regions, even regions in the same country. These are:

1. Livestock population and feed characterisation; and
2. Land use and land use change matrix.

Livestock population and waste characterisation

Due to the fact that livestock populations and waste management systems can vary considerably across regions even in the same country, it is recommended that special attention be given to both the livestock population and feed characterisation.

According to IPCC (2006)[6], "a complete list of all livestock populations …must be developed (e.g. dairy cows, other cattle, buffalo, sheep, goats, camels, llamas, alpacas, deer, horses, rabbits, mules and asses, swine, and poultry) if these categories are relevant, and that more detailed categories should be used if the data are available". For example, more accurate emission estimates can be made if poultry populations are further subdivided (e.g. layers, broilers, turkeys, ducks, and other poultry), as the waste characteristics among these different populations varies significantly.

Of particular use for regions is that agriculture statistics are usually collected at sub-national level (e.g. municipality or province) by national statistic and/or agriculture institutions. These statistics can include comprehensive information about livestock populations and waste management systems. If not, efforts

[5] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_1_Ch1_Introduction.pdf
[6] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf

can be made to create basic statistics at the regional level, that should firstly look to document the following:

- Annual population (per species and categories);
- Dairy cows and milk production; and
- Manure management system (MMS) used per animal population.

Land use and land use change matrix

Carbon stocks differ considerably between the different land use categories (Forest land, Cropland, Grassland and Wetlands), and also, in particular, within the Forest land category, depending on the type of forest (an example is provided in

Figure 4). Therefore, to ensure an accurate estimate of CO_2 emissions and removals at the regional level it is essential to properly identify the different land use and land use changes between the different categories within the region. For the Forest land category, it is also necessary to stratify the category by different types of forest. Such stratification can be done through forest inventories, that normally are developed taking into consideration the main forest types occurring within a country across different locations.

Figure 4: Extract from the aboveground biomass (ABG) stock per type of forest in Indonesia islands[7]

Forest Type	Main Island	Mean AGB (Mg ha-1)	95% Confidence Interval (Mg ha^{-1})	
Primary Dryland Forest	Bali Nusa Tenggara	274,4	247,4	301,3
	Jawa			
	Kalimantan	269,4	258,2	280,6
	Maluku	301,4	220,3	382,5
	Papua	239,1	227,5	250,6
	Sulawesi	275,2	262,4	288,1
	Sumatera	268,6	247,1	290,1
	Indonesia (Average)	266,0	259,5	272,5
Secondary Dryland Forest	Bali Nusa Tenggara	162,7	140,6	184,9
	Jawa	170,5		
	Kalimantan	203,3	196,3	210,3
	Maluku	222,1	204,5	239,8
	Papua	180,4	158,5	202,4
	Sulawesi	206,5	194,3	218,7
	Sumatera	182,2	172,1	192,4
	Indonesia (Average)	197,7	192,9	202,5
Primary Swamp Forest	Bali Nusa Tenggara			
	Jawa			
	Kalimantan	275,5	269,2	281,9
	Maluku			
	Papua	178,8	160	197,5
	Sulawesi	214,4	-256,4	685,2
	Sumatera	220,8	174,7	266,9
	Indonesia (Average)	192,7	174,6	210,8

[7] Indonesia submission for a National Forest Reference Emission Level for Deforestation and Forest Degradation, 2016. Available at: https://redd.unfccc.int/files/frel_submission_by__indonesia_final.pdf

It can be noted in **Figure 4** that the mean aboveground biomass (ABG) stock varies from 162,7 Megagram (1 Mg = 1 tonne) per hectare (in secondary dryland forest) up to 301,4 Mg per hectare (in primary dryland forest), demonstrating that a good stratification is essential for a more accurate estimate of removals.

Together with the stratification, it's recommended to elaborate a "land use and land use change matrix"[8] (see **Appendix 3**) using Approach 3 of the 2006 IPCC Guidelines[9], in order to have an accurate representation of land use and land use change within the borders of the region while ensuring consistency with national estimates.

It is worth highlighting that nowadays, remote sensing imagery can be obtained at spatial resolutions (or grid size) of 25 meters and is becoming less expensive (and in some cases can be obtained free of charge). Examples of global land cover datasets include ESA Climate Change Initiative – Global Land Cover Products[10]; Global Forest Change[11]; Global Forest Watch[12]; MODIS Land Cover Products[13] and Global PALSAR-2/PALSAR/JERS-1 Mosaic and Forest/Non-Forest map[14].

To estimate different carbon stocks, regions can rely on the national estimates that have been developed for national or sub-national REDD+ activities under the UNFCCC[15], as well as for jurisdictional REDD+ proposals[16].

Best practice in Yucatán and across Brazilian states

The following examples are presented to illustrate how national activity data can be disaggregated down to regional level data, and how different tools can be used to estimate regional GHG emissions. Yucatán and one Brazilian state (Pernambuco) were part of the Climate Footprint Project, while three additional Brazilian states (Amazonas, Mato Grosso and São Paulo) received AFOLU-focussed MRV support through the project.

State of Yucatán, Mexico – A working partnership with CONAFOR

Yucatán, Mexico, is a prime example of utilising national AFOLU estimates to build a state-wide inventory for the LULUCF sector. Yucatán embodies 4 million hectares of forestry, making up 75% of its total area, however over the last decade the state has experienced high rates of deforestation (**Figure 5**). Yucatán's

[8] An example of a land use and land use change matrix is presented in the Annexes.
[9] Described at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_03_Ch3_Representation.pdf
[10] http://maps.elie.ucl.ac.be/CCI/viewer/download.php
[11] http://earthenginepartners.appspot.com/science-2013-global-forest
[12] https://www.globalforestwatch.org/
[13] https://modis.gsfc.nasa.gov/data/dataprod/mod12.php
[14] https://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm
[15] https://redd.unfccc.int/
[16] https://verra.org/project/jurisdictional-and-nested-redd-framework/

most recent GHG inventory[17] showed that the Forestry sector is the third highest source of GHG emissions in the region, due to deforestation and forest degradation.

Figure 5: Critical deforestation areas in Yucatán (2001-2018)[18]

Y axis: Superficie en hectáreas = Surface area in hectares
Key: FL-Tierras Forestales = Forest land; GL-Pastizales = Grassland; CL-Tierras de Cultivo = Cropland; WL-Humedales = Wetlands; SL-Asentamientos Humanos = Human Settlements; OL-Otras tierras = Other (types of) Land

To safeguard Yucatán's rich forest landscape, the state has established a REDD+ strategy and strengthened engagement with Mexico's national MRV system. To supplement this, Yucatán has a long-standing history of working closely with CONAFOR[19], the National Forestry Commission, to lead the compilation of their state-level forest inventory. This institutional relationship has proven very fruitful as Yucatán has been able to access national data sets via CONAFOR (i.e. satellite images of land use and land use change) reducing the cost of activity data acquisition and processing.

Furthermore, Yucatán has created a state-level technical MRV system, run by a specialised technical team that is led by the state officials responsible for the state-level GHG inventory and its monitoring.

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[17] https://www.youtube.com/watch?v=XYLwSIYmwEs&list=PLgu0fwHIWaTzckVA4vyeambFKm3XVLr3V&index=14
[18] Source: https://www.gob.mx/conafor/documentos/estimacion-de-la-tasa-de-deforestacion-bruta-en-mexico-para-el-periodo-2001-2018-mediante-el-metodo-de-muestreo
[19] https://www.gob.mx/conafor

Throughout the lifespan of Yucatán's inventory, the specialised MRV team has been guided by CONAFOR. Through open lines of communication, CONAFOR has permitted Yucatán access to historical satellite monitoring data sets of forest land, high-resolution images of forest land generated by the Forest Monitoring Satellite System of CONAFOR[20]. Yucatán was able to use these inputs to assess changes in forestry land in order to quantify the associated GHG emissions in a precise manner. Not only has CONAFOR provided crucial sources of activity data, but it has also guided the team in the application of key methodologies to estimate GHG emissions. This was made possible by running several training sessions between the national and state-level inventory teams, which also helped encourage a transfer of knowledge.

With the support of local, national and international financing sources, access to local experts, as well as data from current studies generated by research centres in the region, could be obtained.

States in Brazil

The Greenhouse Gas Emission and Removal Estimating System (SEEG, from the Portuguese acronym)[21] is a free-of-charge initiative of the Climate Observatory[22] that provides annual estimates of GHG emissions in Brazil, analytical documents on the evolution of emissions and a web portal to provide simple and clear system methods and data. These annual estimates are also allocated across all 26 States, as well as the Federal District of Brazil. In 2019, the allocation reached 96% of the total GHG national emissions estimates (only 4% of the emissions could not be allocated to any state). To allocate the national AFOLU GHG estimates to the state level, SEEG uses several approaches, including:

- Use of national activity data disaggregated by state (e.g. agriculture statistics; land use and land use change areas);
- Use of specific emission factors per emission category per state (as presented in the national GHG inventory); and
- Use of assumptions for determining key parameters per state (based on expert judgment).

It is worth highlighting that the use of the same emission factors and assumptions across the entire time series, may have resulted in under or overestimations, since they don’t necessarily represent the agricultural and/or land use practices used in the state across time, particularly in the first years of the time series. Even known changes in practices that have occurred in the state across the years are not easy to integrate into this top-down method. Nevertheless, SEEG’s sub-national GHG emissions estimates can be used as a first impression for the purpose of understating the GHG emissions profile of each Brazilian state.

[20] https://idefor.cnf.gob.mx/mviewer/samof

[21] Available at: http://seeg.eco.br/en?cama_set_language=en

[22] https://www.oc.eco.br/en/

Figure 6: Mato Grosso Agriculture emissions in 2019[23]

***Fermentação entérica = enteric fermentation is highlighted**

Conclusions

Currently, all countries use the 2006 IPCC Guidelines for National Greenhouse Gas Inventories to estimate GHG emissions and removals from AFOLU. In some cases, national estimates are also disaggregated to the regional level. Proportional distribution of national GHG emissions and removals between regions can be made based on selected indicators (e.g. agricultural production statistics per state or region; aggregate value of agricultural production per state/region; land use areas per state/region, etc.), and while this doesn't provide the same level of accuracy as aggregating from the bottom-up in a region, it is a good place to start.

If a more accurate understanding is needed, it is advisable to estimate AFOLU GHG emissions and removals using specific activity data (AD) and emission factors (EF) that better reflect the agricultural production and/or forest management of a specific region. Specific regional-level AD and EF can be collected from several sources (e.g. IPCC EFDB – emission factor database[24]; FAOSTAT[25]; among others) and should be used to avoid creating methodological inconsistencies between the national and regional estimates.

[23] Source: http://plataforma.seeg.eco.br/map
[24] Available at: https://www.ipcc-nggip.iges.or.jp/EFDB/main.php
[25] Available at: http://www.fao.org/faostat/en/#home

In theory, more accurate estimates could be obtained by applying the 2006 IPCC Guidelines at the regional level, to develop estimates from the bottom-up, but this does come at a cost. Disaggregating emissions and removals from the national GHG inventory by using specific criteria and assumptions can be technically challenging but is often still simpler than developing bottom-up regional estimates. Both approaches however do depend on the availability of data and information, as well as the current level of technical capacity at the regional level, and the human and financial resources available.

In any case, AFOLU GHG emissions and removals inventories are a "learning-by-doing" exercise, where improvements can be achieved across the inventory cycles, through constant evaluation, feedback and planning. In this regard, regions should endeavour to coordinate efforts with their national entities that are responsible for the national GHG inventory in order to gain experience and optimize efforts. In addition, coordination between regions with similar characteristics should also be encouraged, particularly in the Forestry sector where activity data (e.g. satellite images) could be obtain and processed for all regions at once, diminishing the costs. This is a positive aspect of the Under2 Coalition, that states and regions from across the globe can interact and exchange knowledge and experience in pursuing their commitment to ambitious climate action in line with the Paris Agreement.

Finally, in opening this technical knowledge product with an explanation of the relation of the AFOLU sector to GHG emissions then detailing how to use a 4-step decision tree for obtaining estimates, followed by an introduction to two common sets of AFOLU sector AD and three examples of subnational best practice, it is hoped that the AFOLU sector has been demystified. And that the subnational government reader now understands how and where to start their state or region's journey in estimating AFOLU sector emissions and removals.

This project is part of the International Climate Initiative (IKI)
The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) supports this initiative on the basis of a decision adopted by the German Bundestag.

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Appendix 1 – List of potential key AFOLU sources/categories

For the **Agriculture sector**, the potential GHG sources/categories of emissions are:

- **CH_4 from enteric fermentation:** "Methane is produced in herbivores as a by-product of enteric fermentation (…). The amount of methane that is released depends on the type of digestive tract, age, and weight of the animal, and the quality and quantity of the feed consumed." (IPCC, 2006).
- **CH_4 and N_2O from manure management:** Methane and nitrous oxide are "produced during the storage and treatment of manure, and from manure deposited on pasture. The term 'manure' is used here collectively to include both dung and urine (i.e. the solids and the liquids) produced by livestock" (IPCC, 2006).
- **CO_2 from liming:** "Liming is used to reduce soil acidity and improve plant growth in managed systems, particularly agricultural lands and managed forests. Adding carbonates to soils in the form of lime (e.g. calcic limestone ($CaCO_3$), or dolomite ($CaMg(CO_3)_2$) leads to CO_2 emissions as the carbonate limes dissolve and release bicarbonate ($2HCO_3$-), which evolves into CO_2 and water (H_2O)" (IPCC, 2006).
- **CO_2 from urea application:** "Adding urea to soils during fertilisation leads to a loss of CO_2 that was fixed in the industrial production process. (…) Similar to the soil reaction following addition of lime, bicarbonate that is formed evolves into CO2 and water" (IPCC, 2006).
- **Direct N_2O emissions from managed soils:** "In most soils, an increase in available N enhances nitrification and denitrification rates which then increase the production of N_2O. Increases in available N can occur through human-induced N additions or change of land-use and/or management practices that mineralise soil organic N" (IPCC, 2006).
- **Indirect N_2O emissions from managed soils:** "In addition to the direct emissions of N_2O from managed soils that occur through a direct pathway (i.e. directly from the soils to which N is applied), emissions of N_2O also take place through two indirect pathways:
    - Volatilisation of N as NH_3 and oxides of N (NO_x), and the deposition of these gases and their products NH_4+ and NO_3- onto soils and the surface of lakes and other waters; and
    - Leaching and runoff from land of N from synthetic and organic fertiliser additions, crop residues, mineralisation of N associated with loss of soil C in mineral and drained/managed organic soils through land-use change or management practices, and urine and dung deposition from grazing animal" (IPCC, 2006).
- **Indirect N_2O emissions from manure management:** "Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and NO_x." (IPCC, 2006).
- **CH_4 from rice cultivation:** "Anaerobic decomposition of organic material in flooded rice fields produces methane (CH_4), which escapes to the atmosphere primarily by transport through the rice plants" (IPCC, 2006).

- **CH_4, N_2O, CO, NOx and NMVOC from field burning of agriculture residues:** "Emissions from fire include not only CO_2, but also other greenhouse gases, or precursors of greenhouse gases, that originate from incomplete combustion of the fuel. These include carbon monoxide (CO), methane (CH_4), non-methane volatile organic compounds (NMVOC) and nitrogen (e.g. N_2O, NO_x) species".

For the **LULUCF sector**, the potential GHG sources/categories of emissions and removals are:

- **CO_2 emissions and removals from land use and land use change**, due to changes in carbon stocks in carbon pools (i.e. aboveground and belowground biomass, deadwood, litter and soil organic matter[26]) in the following land use categories:
    - **Forest land:** "includes all land with woody vegetation consistent with thresholds used to define Forest Land in the national GHG inventory. It also includes systems with a vegetation structure that currently fall below, but in situ could potentially reach the threshold values used by a country to define the Forest Land category" (IPCC, 2006).
    - **Cropland:** "includes cropped land, including rice fields, and agroforestry systems where the vegetation structure falls below the thresholds used for the Forest Land category" (IPCC, 2006).
    - **Grassland:** "includes rangelands and pastureland that are not considered Cropland. It also includes systems with woody vegetation and other non-grass vegetation such as herbs and brushes that fall below the threshold values used in the Forest Land category. The category also includes all grassland from wild lands to recreational areas as well as agricultural and silvopastural systems, consistent with national definition" (IPCC, 2006).
    - **Wetlands:** "includes areas of peat extraction and land that is covered or saturated by water for all or part of the year (e.g. peatlands) and that does not fall into the Forest Land, Cropland, Grassland or Settlements categories. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions" (IPCC, 2006).
    - **Settlements:** "includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories" (IPCC, 2006).
    - **Other land:** "includes bare soil, rock, ice, and all land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available" (IPCC, 2006).
- **CH_4, N_2O, CO, NOx and NMVOC from biomass burning** in the above land use categories (not including field burning of agriculture residues).

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[26] The 2006 IPCC definitions for the carbon pools are presented in **Appendix 2.**

Appendix 2 – Definitions for carbon pools used in AFOLU for each land use category[27]

TABLE 1.1
DEFINITIONS FOR CARBON POOLS USED IN AFOLU FOR EACH LAND-USE CATEGORY

Pool		Description
Biomass	Above-ground biomass	All biomass of living vegetation, both woody and herbaceous, above the soil including stems, stumps, branches, bark, seeds, and foliage. Note: In cases where forest understory is a relatively small component of the above-ground biomass carbon pool, it is acceptable for the methodologies and associated data used in some tiers to exclude it, provided the tiers are used in a consistent manner throughout the inventory time series.
	Below-ground biomass	All biomass of live roots. Fine roots of less than (suggested) 2mm diameter are often excluded because these often cannot be distinguished empirically from soil organic matter or litter.
Dead organic matter	Dead wood	Includes all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps, larger than or equal to 10 cm in diameter (or the diameter specified by the country).
	Litter	Includes all non-living biomass with a size greater than the limit for soil organic matter (suggested 2 mm) and less than the minimum diameter chosen for dead wood (e.g. 10 cm), lying dead, in various states of decomposition above or within the mineral or organic soil. This includes the litter layer as usually defined in soil typologies. Live fine roots above the mineral or organic soil (of less than the minimum diameter limit chosen for below-ground biomass) are included in litter where they cannot be distinguished from it empirically.
Soils	Soil organic matter[1]	Includes organic carbon in mineral soils to a specified depth chosen by the country and applied consistently through the time series[2]. Live and dead fine roots and DOM within the soil, that are less than the minimum diameter limit (suggested 2 mm) for roots and DOM, are included with soil organic matter where they cannot be distinguished from it empirically. The default for soil depth is 30 cm and guidance on determining country-specific depths is given in Chapter 2.3.3.1.

[1] Includes organic material (living and non-living) within the soil matrix, operationally defined as a specific size fraction (e.g., all matter passing through a 2 mm sieve). Soil C stock estimates may also include soil inorganic C if using a Tier 3 method. CO_2 emissions from liming and urea applications to soils are estimated as fluxes using Tier 1 or Tier 2 method.

[2] Carbon stocks in organic soils are not explicitly computed using Tier 1 or Tier 2 method, (which estimate only annual C flux from organic soils), but C stocks in organic soils can be estimated in a Tier 3 method. Definition of organic soils for classification purposes is provided in Chapter 3.

[27] Source: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_01_Ch1_Introduction.pdf

Appendix 3 – Example of a land use and land use change matrix[28]

TABLE 3.5

ILLUSTRATIVE EXAMPLE OF APPROACH 2 DATA IN A LAND-USE CONVERSION MATRIX WITH CATEGORY STRATIFICATION

Initial / Final	Forest Land (unman-aged)	Forest Land (managed, temperate continental)	Forest Land (managed, boreal conifer-ous)	Grassland (unim-proved)	Grass-land (im-proved)	Cropland	Wetlands	Settle-ments	Other Land	Final area
Forest Land (unman-aged)	5									**5**
Forest Land (managed, temperate continental)		4		1	2	1				**8**
Forest Land (managed, boreal coniferous)			6							**6**
Grassland (unim-proved)		2		61						**63**
Grassland (improved)				2	17					**19**
Cropland						29				**29**
Wetlands							0			**0**
Settlements		1		1		1		5		**8**
Other Land									2	**2**
Initial area	**5**	**7**	**6**	**65**	**19**	**31**	**0**	**5**	**2**	**140**
Net change	0	1	0	-2	0	-2	0	+3	0	0

Note: Column and row totals show net conversion of land use as presented in Table 3.3. "Initial" indicates the category at a time previous to the date for which the assessment is made and "Final" the category at the date of assessment. Net changes (bottom row) are the final area minus the initial area for each of the (conversion) categories shown at the head of the corresponding column. Blank entry indicates no land-use conversion for this transition.

[28] Source: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_03_Ch3_Representation.pdf