LULUCF and SEEA CF

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Introduction

The rate of build-up of carbon dioxide (CO2) in the atmosphere can be reduced by taking advantage of the fact that atmospheric CO2 can accumulate as carbon in vegetation and soils in terrestrial ecosystems. Under the United Nations Framework Convention on Climate Change (UNFCCC) any process, activity or mechanism which removes a greenhouse gas (GHG) from the atmosphere is referred to as a "sink"[1]. Human activities impact terrestrial sinks, through land use, land-use change and forestry, consequently, the exchange of CO2 (carbon cycle) between the terrestrial biosphere and the atmosphere is altered. Land use, land-use change and forestry (LULUCF) is a sector defined by IPCC, that looks at both carbon emissions and carbon sequestration related to land use and land use changes. There is growing policy interest in this sector as the management of terrestrial ecosystems (mainly forests) provides several climate change mitigation options. LULUCF carbon removals and emissions are part of national and international climate mitigation targets, for example, as set for the Paris Climate Agreement in 2015.

The SEEA CF does not provide clear guidance how to treat emissions and uptake of CO2 that result from land use and land use change. As a result, LULUCF emissions and uptake are (usually) not included in SEEA air emission accounts (AEA). For example, the European air emission accounts as defined by the underlying legal base do not include emissions from the LULUCF sector. Given the increasing importance of LULUCF in EU's climate policy, Eurostat recently came up with a proposal to amend for this by including LULUCF emissions and removals as a memorandum item to identify differences between AEA totals and national totals derived from UNFCCC greenhouse gas inventories (Eurostat, 2022).

This issue was first addressed by FAO 6-7 years ago for the compilation of SEEA AFF and also discussed in the London group (Tubielli, 2016; Tubielli et al., 2017). For the SEEA AFF is was concluded that all LULUCF emissions and uptake should be included, but acknowledged that this interpretation was 'at the edge of current SEEA understanding and applications' (FAO, 2016).

In this paper we will revisit the question a) whether LULUCF related carbon emissions and uptake should be included in SEEA, and more particularly in the SEEA CF air emission accounts, and b) if they are to be included to what industries these emissions / uptake should be allocated. First, a short overview of the

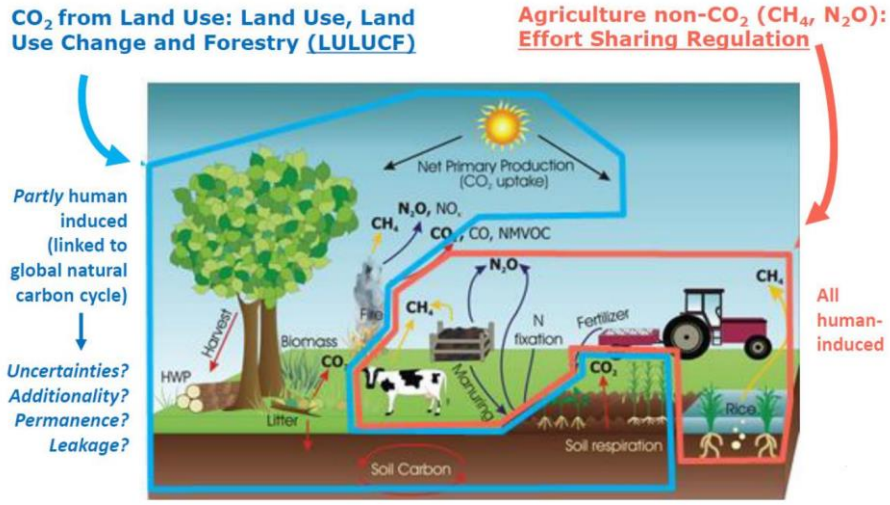
[1] https://unfccc.int/topics/land-use/workstreams/land-use--land-use-change-and-forestry-lulucf

key characteristics of LULUCF will provided. Next, the current guidance in SEEA CF will be presented. Then we will discuss the key issue by addressing the arguments for inclusion or exclusion of LULUCF in the SEEA AEA. Accordingly, there are several accounting options that will be presented and discussed. Finally, we will draw some conclusions and discuss a possible way forward.

What is LULUCF?

Land use, Land-use Change, and Forestry (LULUCF) is defined by the UNFCCC as **a greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human-induced land use, land use change and forestry activities** (UNFCCC, 2012). It thus covers emissions and removals of greenhouse gases (CO2, N2O and CH4) resulting from direct human-induced land use (agriculture, forestry, wetlands, settlements etc.), land-use change, and forestry activities.

The LULUCF sector is different from the other sectors defined by the UNFCCC as it a) includes emissions from biomass (all other sectors exclude biomass related flows as they are short cyclic), and b) includes not only emissions but also removals of carbon from the atmosphere. The LULUCF sector also is closely connected to the Agriculture sector. The figure below explains the scope difference between the two sectors.



UNFCCC greenhouse gas emission inventories distinguish the following sub-sectors of LULUCF (see also table below): forest land, cropland, grassland, wetlands, settlements, other land, harvested wood products, other land use, land use change, and forestry, managed soils - indirect N2O emissions. These subsectors thus represent some key land use categories (as defined by the UNFCCC) plus some extra categories such as harvested wood products etc.

Greenhouse gas emissions by LULUCF sector; EU 1990-2019, million tonnes CO_2-equivalents

CRF code	CRF label	1990	2000	2010	2019
CRF4	Land use, land use change, and forestry (LULUCF)	-211	-306	-315	-249
CRF4A	*Forest land*	*-335*	*-397*	*-405*	*-329*
CRF4A0	Drainage and rewetting and other management of organic and mineral soils related to forest land - emissions and removals	7	7	6	6
CRF4A1	Unconverted forest land	-304	-357	-356	-297
CRF4A2	Land converted to forest land	-38	-47	-55	-39
CRF4B	*Cropland*	*66*	*59*	*51*	*41*
CRF4B0	Drainage and rewetting and other management of organic and mineral soils related to cropland - emissions and removals	5	4	4	4
CRF4B1	Unconverted cropland	23	19	7	3
CRF4B2	Land converted to cropland	38	36	40	34
CRF4C	*Grassland*	*34*	*24*	*14*	*13*
CRF4C0	Drainage and rewetting and other management of organic and mineral soils related to grassland - emissions and removals	3	3	3	3
CRF4C1	Unconverted grassland	49	42	35	31
CRF4C2	Land converted to grassland	-17	-21	-24	-21
CRF4D	*Wetlands*	*13*	*13*	*17*	*17*
CRF4D0	Drainage and rewetting and other management of organic and mineral soils related to wetlands - emissions and removals	2	2	2	2
CRF4D1	Unconverted wetlands	8	9	10	10
CRF4D2	Land converted to wetlands	2	3	5	5
CRF4E	*Settlements*	*35*	*37*	*42*	*44*
CRF4E0	Biomass burning in settlements	0	0	0	0
CRF4E1	Unconverted settlements	2	2	2	2
CRF4E2	Land converted to settlements	33	35	40	42
CRF4F	*Other land*	*4*	*1*	*1*	*2*
CRF4F2	Land converted to other land	3	0	0	0
CRF4F3	Nitrogen mineralization and immobilization in other land - direct N2O emissions	1	1	1	1
CRF4F4	Biomass burning on other land	0	0	0	0
CRF4G	*Harvested wood products*	*-29*	*-46*	*-38*	*-38*
CRF4H	*Other land use, land use change, and forestry*	*0*	*1*	*0*	*0*
CRF4Z	*Managed soils - indirect N2O emissions*	*1*	*1*	*1*	*1*

Source: EEA re-published by Eurostat (env_air_gge)

As can also be deduced from the table above, accounting for the LULUCF emissions and removals is quite complex. Basically, we can summarize it as follows:

1) Emissions and absorptions linked to **land use**, including
- Growth of trees, leading to absorption of carbon (carbon sequestration)
- Biomass mortality, wood removal in forests, forest fires, leading to carbon emissions
- Impacts of changes in agricultural practices on cultivated soils, etc.

2) Emissions and absorptions linked to **changes in land use,** including
- Deforestation,
- Afforestation,
- Soil artificialisation, etc.

3) **Harvested Wood Products** (HWPs). HPWs are wood-based materials harvested from forests, which are used for products such as furniture, plywood, paper and paper-like products, or for energy. It is assumed that all carbon removed in wood and other biomass from forests is oxidized and emitted to the atmosphere in the year of removal.

Guidance in the SEEA CF

In this section we will review the current guidance that can be deduced from the SEEA CF (2012). As already mentioned in the introduction, the SEEA Central Framework does provide very limited guidance with regard to LULUCF related flows in the AEA. Below we list and discuss the main references.

With regard to emissions related to land use and land conversions the following paragraph is most relevant:

3.243 Included within the scope of air emissions in the air emissions account is a range of other emissions that are the direct result of economic production processes, namely, the emissions from cultivated livestock due to digestion (primarily methane), and ***emissions from soil as a consequence of cultivation or of other soil disturbances, arising, for example, from construction or land clearance. Emissions from natural processes such as unintended forest and grassland fires*** *and human metabolic processes which are not the direct result of economic production* ***are excluded****.*

This paragraph clarifies that emissions from soils are included in the scope of the SEEA AEA as long as they result directly from certain economic activities such as agriculture or construction. At the same time it is stressed that emissions from natural processes, such as unintended forest and grassland fires, are to be excluded. Furthermore, by referring to land clearance this paragraph seems to imply that emissions due to land use changes are included in the scope.

With regard to <u>removal / sequestration of gasses</u> the following two paragraphs are relevant:

3.242 Air emission accounts also ***do not record*** *the extent of* ***the capture or embodiment of gases by the environment****, for example, carbon captured in forests and soil.*

3.234 Gaseous and particulate substances ***generated through economic activity may be captured*** *for use in other production processes or transferred between economic units for use in production* ***or for storage*** *(e.g., of carbon emissions).*

At first sight par. 3.242 is clear on the exclusion of the capture/uptake of gases in the air emissions accounts. However, it is stated that this refers to capture of gases *by the environment*, thus it is not clear if this only refers to the 'natural environment' or also to the 'managed environment'. In other words, if this also refers to the uptake of CO2 as defined in LULUCF. Furthermore, it is also not clear whether the exclusion is based purely on conceptual reasons or that, by definition, the air *emission* accounts should only include emissions and not uptake. Here, it is important to note that, looking beyond the AEA, CO2 is recognized in the SEEA CF as an important natural input that should be recorded in the general physical supply and use tables (PSUTs). As such, SEEA CF does not preclude the recording of CO2 uptake from the atmosphere. Paragraph 3.234 indicates that the AEA could go beyond just recoding emissions by also including the capture or storage of CO2 produced by economic activities. Thus, this leaves open the possibility of including the removals of CO2 from the atmosphere due to economic activities in the AEA.

Discussion

In this section we will address the key issue: *Should LULUCF emissions and removals be included in the scope of the SEEA AEA or not?* Basically, this means that we must look at the following two questions:

a. Do LULUCF carbon removals concur with the definition of natural inputs as defined in SEEA CF, i.e. *physical inputs that are moved from their location in the environment as a part of economic production processes or are directly used in production ?*
b. Do LULUCF emissions concur with the definition of air emissions as defined in SEEA CF, i.e. *gaseous and particulate substances released to the atmosphere by establishments and households as a result of production, consumption and accumulation processes ?*

When investigating this issue, there are both the arguments pro and contra for inclusion of LULUCF.

We start by looking more closely to the general definition and scope of the IPCC emissions, and LULUCF emissions and removals more specifically. Basically, the scope of IPCC emissions includes all **anthropogenic emissions**, which are defined as *emissions of greenhouse gases (GHGs), precursors of GHGs and aerosols **caused by human activities*** (IPCC Glossary, 2022). These activities include the burning of fossil fuels, deforestation, land use and land-use changes (LULUC), livestock production, fertilization, waste management and industrial processes. Here we see in principle a close correspondence with the definition of air emissions in SEEA (see above): both are focused on emissions induced by human activities, which we can assume are the same as economic activities as defined in the SNA/ SEEA context.

LULUCF covers anthropogenic emissions and removals of GHG in managed lands, excluding non-CO2 agricultural emissions. Following the 2006 IPCC Guidelines for National GHG Inventories and their 2019 Refinement, **'anthropogenic' land-related GHG fluxes are defined as all those occurring on 'managed land',** that is, **'where human interventions and practices have been applied to perform production, ecological or social functions'.** Furthermore, anthropogenic removals refer to the withdrawal of GHGs from the atmosphere **as a result of deliberate human activities**. These include enhancing biological sinks of CO2 and using chemical engineering to achieve long-term removal and storage. Finally, emissions and removals related to land use change by definition are human induced. From this we can deduce that LULUCF emissions and removals in principle include only flows that are the result of human interventions. Accordingly, we may conclude that LULUCF flows would be within scope of SEEA and thus should be included in the AEA.

A non-conceptual argument to include LULUCF in the AEA is that these flows are highly policy relevant. Particularly for countries with a lot of forests, LULUCF provides a way of recording mitigation options by sequestering carbon from the atmosphere. Likewise, some countries may have large emissions from organic soils which otherwise would not be recorded. Exclusion of LULUCF would also create another difference between AEA and the IPCC data. Users of the data may not understand why these 'anthropogenic' emissions are not included.

There are however also arguments against including LULUCF in the SEEA AEA:

First, more in general, conceptually flows occurring solely within the environment are out of scope of physical supply and use tables (SEEA CF par 3.23). The one example provided in the SEEA is 'evaporation and precipitation of water and soil moved through soil erosion'. It could be argued that LULUCF emissions and removals are quite similar as the example just cited, and thus should also be interpreted

as flows within the environment. For example, emissions from organic soils in principle primarily reflect a natural process occurring within the natural environment. To some degree (or in certain cases) this may be human induced (drainage of peat soils for example), but the point is that these emissions may also (in many cases) be not anthropogenic in origin.

Second, and more specific, emissions and removals resulting from land use in many cases do not correspond to emissions and natural inputs as defined in the SEEA. To investigate this we have to look more closely at the definitions for land use. According to IPCC land use is *defined as the total of arrangements, activities and inputs undertaken in a certain land cover type (a set of human actions*) (IPCC glossary, 2022). In SEEA CF, land use reflects both *(a) the activities undertaken and (b) the institutional arrangements put in place for a given area for the purposes of economic production, or the maintenance and restoration of environmental functions* (SEEA CF par 5.246). In effect, "use" of an area implies the existence of some human intervention or management. Land in use therefore includes, for example, protected areas, that are under the active management of institutional units of a country for the purpose of excluding economic or human activity from that area. Furthermore, some areas are "not in use", although they may have a use in supporting ecosystems and biodiversity. From these definitions we can deduce a) that IPCC and SEEA use a very similar definition of land use, and b) land use is much broader that the economic activity taking place on the land. By looking at the land use classification from the SEEA CF, in effect we can distinguish three categories 1) land use directly associated with an economic production/ consumption activity, 2) land use associated with and environmental management activity (in other words, land under environmental protection), and 3) land not in use.

1 Land		
	1.1 Agriculture	Economic production activity
	1.2 Forestry	Economic production activity
	1.3 Land used for aquaculture	Economic production/ consumption activity
	1.4 Use of built-up and related areas	Economic production activity
	1.5 Land used for maintenance and restoration of environmental functions	Environmental management activity
	1.6 Other uses of land n.e.c.	
	1.7 Land not in use	land not in use

In principle environmental management activities could be seen as another production activity. However, ecosystem management is very different from for example production activities involving combustion processes (CO2 emissions) or agricultural processes (methane emissions). We conclude that land use is a broader concept than the production activity taking place on the land, and accordingly, not all emissions / uptake associated with land use can be associated with an economic activity.

Basically, the main problem with the IPCC guidelines for LULUCF is that they use a very broad interpretation for land management, i.e. all human interventions and practices that have been applied to perform production, ecological or social functions. The guidelines also acknowledge that: 'Since managed land may include carbon dioxide (CO2) removals not considered as 'anthropogenic' in some of the scientific literature assessed in this report (e.g., removals associated with CO2 fertilisation and N deposition), the land-related net GHG emission estimates from global models are not necessarily directly comparable with LULUCF estimates in National GHG Inventories'. (IPCC 2006, 2019). Summarizing, including LULUCF related flows would 'blur' the boundary between the economy and the environment, as all terrestrial ecosystems that are somehow managed would be included into the economic sphere.

Finally, and related with the above arguments, including LULUCF uptake as a natural input into the economy and LULUCF emissions as emissions from the economy seems contradictory with carbon sequestration/ carbon emissions from organic soils etc. as described and recorded in the SEEA EA. Carbon sequestration in SEEA EA is an ecosystem service, a key example of an ecological process (carbon uptake from the atmosphere by photosynthesis into biomass) that provides benefits to society (global climate regulation). It is hard to reconcile on the one hand the view that carbon sequestration represents a natural input flow into the economy (SEEA CF) and on the other hand the view that this is a flow into ecosystems assets that represents an ecosystem service provided to the economy/society.

Options for accounting for LULUCF

Although the discussion above shows it is not be immediately obvious whether LULUCF should be included or not in the AEA, looking at how the LULUCF flows may be accommodated in an accounting framework may help solving the issue. Below we present three different options, using some example data for LULUCF.

Example IPCC data for LULUCF and combustion

LULUCF	kton CO2
Forest land	
Emissions from organic soils	30
Carbon uptake	-400
Land converted to forests	-45
Cropland	
Emissions from organic soils	80
Land converted to cropland	25
Wetlands	
Emissions from soils/ sediment	15
Land converted to wetland	5
Settlements	
Land converted to settlements	35
Harvested wood products	20

Combustion	kton CO2
Agriculture	110
Forestry	20
Mining and manufactering	580
Government	90
Households	250

Option 1: Exclude (by convention) all LULUCF related emissions and uptake in SEEA CF air emission accounts. Basically, this would follow the argumentation that these flows (mainly) represent flows that occur within the environment and are (mainly) not directly related to production of consumption activities. This option obviously would not change anything in the current recording of the AEA.

Option 2: Include all LULUCF related emissions and uptake in SEEA CF air emission accounts and allocate the emissions and uptake to de relevant economic sectors. This option follows the opposite reasoning, i.e. LULUCF by definition represent anthrophonic emissions and thus should be included in the AEA. Accordingly, including emissions related to land use and land use changes in de SEEA AEA would require to allocate these emissions to the economic units responsible for the emissions.

Emissions and CO2 uptake related to land use should be allocated to the production activity directly related to the land use. For example, emissions from agricultural lands are to be allocated to Agriculture (ISIC A). This may not always be straightforward. For (semi) natural areas, protected and non-protected, there often is no clear link to an economic activity. In this case the allocation should be to the activity responsible for the management of the land (which in many cases may be the government). For settlements there may be multiple economic activities involved, including households. Here emissions should be split out to the different activities or (by default) be allocated to households.

For emissions related to land use change it is more complicated. For example, when a forest is cleared to make way for agriculture (deforestation), emissions may be attributed to the forestry sector (the old land use, who would in this case also be probably active in the actual clearing of the land) or to agriculture (the new land use). There are both valid arguments for allocation to the old or new land use. It is proposed here to allocate by default the emissions to the economic activity that is active in the new land use (which could be a production activity but also a consumption activity, i.e. households). The main argument is that the new land use is the driver for the land use change and thus for the related emissions (or uptake).

The tables for CO2 below show how the recording of LULUCF would work. Adding uptake from the atmosphere would introduce a use table (normally for the AEA only the supply table is compiled). Based on the supply and use tables also the net emissions / uptake per sector can be calculated.

Supply	**Agriculture**	**Forestry**	**Mining and manufactering**	**Government**	**Households**	**Environment (atmosphere)**	**Total**
CO2 combustion	110	20	580	90	250		1050
CO2 land use	80	30		15		400	525
CO2 land use change	25			5	35	45	110
CO2 harvested wood products		20					20
Total	**215**	**70**	**580**	**110**	**285**	**445**	**1705**

USE	**Agriculture**	**Forestry**	**Mining and manufactering**	**Government**	**Households**	**Environment (atmosphere)**	**Total**
CO2 combustion						1050	1050
CO2 land use		400				125	525
CO2 land use change		45				65	110
CO2 harvested wood product	0		0	0	0	20	20
total	**0**	**445**	**0**	**0**	**0**	**1260**	**1705**
Net emissions/ uptake	215	-375	580	110	285	-815	

Option 3: record LULUCF flows as directly related to terrestrial ecosystems. In this alternative option, the LULUCF flows are also recorded in the AEA, but not directly to and from economic activities. Instead, the flows are recorded as they actually occur, namely to and from the respective terrestrial ecosystems.

This would be done by introducing the main land use categories is the column headings. This option reflects the consideration that these flows to a large degree occur within the environment.

However, this recoding requires a more complex setup of the AEA (i.e. more complex than option 1) with the additional entry of ecosystem types. Also, this option leaves it open whether LULUCF emissions / uptake should be included in the total resident emissions, the key indicator to be derived from the AEA.

Supply	Forests	Wetlands	Croplands	Build up land	Agriculture	Forestry	Mining and manufacturing	Government	Households	Environment (atmosphere)	Total
CO2 combustion					110	20	580	90	250		1050
CO2 land use	30	15	80							400	525
CO2 land use change		5	25	35						45	110
CO2 harvested wood prod	20										20
Total	**50**	**20**	**105**	**35**	**110**	**20**	**580**	**90**	**250**	**445**	**1705**

USE	Forests	Wetlands	Croplands	Build up land	Agriculture	Forestry	Mining and manufacturing	Government	Households	Environment (atmosphere)	Total
CO2 combustion										1050	1050
CO2 land use	400									125	525
CO2 land use change	45									65	110
CO2 harvested wood products										20	20
Total	**445**									**1260**	**1705**

Conclusions and way forward

The key issue addressed in this paper, *should LULUCF emissions and removals be included in the scope of the SEEA AEA or not?* is not easily answered. On the one hand there are conceptual arguments for inclusion, primarily as all IPCC related emissions, including LULUCF, in principle should be human induced. In addition, there is a clear policy demand to also account for these flows. On the other hand, inclusion of LULUCF emissions and uptake would mean a very broad interpretation of land management as an economic production activity and would blur the economy-environment boundary as defined in the SEEA context.

Basically, the in depth analysis of LULUCF shows that conceptually part of the flows should be included in the AEA and part not. Included are flows related to agricultural land use and forestry, and also the flows related to land use change. Excluded are flows that occur in natural environments and their associated land use categories (wetlands, other land use etc.). However, there is a grey area, for example forests that are not used for forestry, and in practice it may be difficult to put this into practice.

The accounting examples provided here show that in principle LULUCF emissions and uptake can be accommodated in the AEA. Allocation to ISIC (option 2) is in most cases straightforward, although in some cases specific guidance is required. Allocation of LULUCF flows not directly to ISIC, but to ecosystems (option 3) may be interesting, as it is based on the flows as they actually occur and provides a direct link to the SEEA EA.

A possible way forward may be to decide that, for practical reasons, to include *by convention* LULUCF in the AEA. In SEEA and the AEA there are already some precedents for this. For example, it recommended that by convention emissions due to anthropogenic respiration are excluded, although conceptually there is no good reason to do so (the main reason for exclusion was that these emissions are not very

policy relevant, but also to concur with the IPCC guidelines). So similarly, this approach could be applied to LULUCF, in this case to include these flows by convention in the AEA, while remarking that there may be some issues with the scope.

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