CO_2 Human Emissions

Report on workshops organised by CHE

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Co-ordinated by ECMWF

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CHE: CO2 Human Emissions Project

Coordination and Support Action (CSA)
H2020-EO-3-2017 Preparation for a European capacity to monitor CO_2 anthropogenic emissions

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1 Introduction

1.1 Background

As one of its final activities before the project comes to an end, CHE organised a workshop with experts around Europe on the topic of emission reporting for the AFOLU sector. The AFOLU (Agriculture, Forestry and Other Land Use) sector is a critical part of the (anthropogenic) carbon cycle and can play an important role in terms of mitigation efforts through an enhancement of removals of greenhouse gases, as well as reduction of emissions through management of land, vegetation and livestock. The AFOLU sector therefore plays an important role in the Paris Agreement and especially in the Nationally Determined Contributions (NDCs). In fact, the GHG inventory of the European Union for Land Use, Land Use Change, and Forestry (LULUCF) and agriculture is based on the Greenhouse Gas (GHG) Monitoring Mechanism regulation 525 (2013), the new Regulations on LULUCF 841 (2018) and the Energy Union 1999 (2018). From 2023 onwards, the post-2020 reporting of the EU GHG inventory will be based on Regulation 1999 (replacing Regulation 525) and includes for the first time the LULUCF sector (under LULUCF 841) into the 2030 EU climate targets. This requires increasing the confidence of LULUCF estimates for more reliable GHG inventories to monitor the progress towards reduction targets. As such, the LULUCF inventory will not only undergo a QA/QC check (as has been the case so far), but also a substantial European revision (and, where needed, correction) as is done for all other sectors. This means a significant effort to increase the accuracy of estimates and thus the trust on LULUCF numbers, for which Earth Observation/Copernicus data are needed.

The CHE project was therefore asked by the CO2 Monitoring Task Force to hold a workshop to clarify the different definitions and methods used in the current reporting and identify a roadmap for greenhouse gas monitoring of the AFOLU sector and its components as part of the Copernicus anthropogenic CO_2 emissions Monitoring and Verification Support (CO2MVS) capacity.

The workshop, which was by invitation only to keep the discussion dynamic and focused, attracted around 40 participants from the European Commission, the CHE and VERIFY projects, some EU member states, the IPCC, the EEA and the JRC. The discussions touched on four themes (international and European reporting requirements, EU member state reporting, the role of Earth Observation, and current state of science activities), which were all introduced by one of the speakers. There was also a presentation reporting on an earlier workshop from the VERIFY project that had touched on some of these aspects as well. Discussions supported by an online interaction platform were lively and helped to create a better understanding between the different communities and to generate some good ideas about the potential of the Copernicus CO2MVS to support the reporting and monitoring challenges around the AFOLU sector.

All presentations, which provide a very good and up-to-date overview of the current state of affairs regarding the AFOLU reporting, can be found at https://www.che-project.eu/events/afolu-workshop.

1.2 Scope of this deliverable

1.2.1 Objectives of this deliverables

The original objective of this deliverable was to organize a workshop open to the wider community to discuss, document and learn from the various efforts outside the project. The workshop would aim to address the open questions for an emission monitoring system involving worldwide experts. In consultation with the European Commission's CO_2 Monitoring Task Force, it was decided to slightly deviate from the original approach and organise a

smaller focused workshop with invited participants from the European community involved in the various aspects of the reporting for the AFOLU sector. This was supported by the fact that the estimation of CO_2 emissions from the AFOLU sector can likely benefit more from the envisaged CO_2 Monitoring and Verification Support Capacity, reconciling bottom-up statistics with top-down measurements, than the estimation of fossil fuel CO_2 emissions, as was also shown in the H2020 project VERIFY

1.2.2 Work performed in this deliverable

This deliverable is a summary report of the workshop.

2 Summary of workshop discussions

The workshop, which was by invitation only to keep the discussion dynamic and focused, attracted 48 participants on the first day and 41 participants on the second day. They represented the European Commission, the CHE and VERIFY projects, some EU member states, the IPCC, the EEA and the JRC. The discussions touched on four themes (international and European reporting requirements, EU member state reporting, the role of Earth Observation, and current state of science activities), which were all introduced by one of the invited speakers. There was also a presentation reporting on an earlier workshop from the VERIFY project that had touched on some of these aspects as well. Discussions supported by an online interaction platform were lively and helped to create a better understanding between the different communities and to generate some good ideas about the potential of the Copernicus CO2MVS to support the reporting and monitoring challenges around the AFOLU sector.

2.1 Day 1

The workshop was introduced by Gianpaolo Balsamo (ECMWF, CHE project coordinator) and Richard Engelen (ECMWF, organiser of workshop). Gianpaolo briefly presented an overview of the current status of CHE and an outlook for the follow-on CoCO2 project. He emphasized the importance of the AFOLU sector within the global carbon budget. Moreover, the role of the AFOLU sector is increasing because of its potential for mitigation of emissions Richard then introduced the planned Copernicus CO_2 emission Monitoring & Verification Support capacity and went on to summarize the aims of the workshop and how the two days were organised.

The first introductory presentation was given by Giacomo Grassi (JRC) on the perspective from the UNFCCC/IPCC/EU. He stressed the importance of understanding and aligning the definitions used by the various groups (e.g., scientists vs. reporting agencies) for the AFOLU sector. There are good reasons for the differences in definitions, but it makes it difficult to directly compare estimates. He also discussed the completeness of the reporting and the uncertainties of the reporting. The latter are still significant, although they have been reduced over the last decade or so. He finished by commenting on the added value of models and Earth Observation: Independent verification, greater spatial and temporal resolution of activity data (e.g., forest cover change) and emission factors (e.g., biomass maps), hotspots (natural disturbances), completeness (soils?) and better understanding of the drivers. As next challenges he identified the following: clarify system boundaries and definitions to find common grounds: (i) Greater transparency by countries (what process is included, maps etc); (ii) Flexibility/modularity by models.

The second presentation was by Marina Vitullo (ISPRA) covering the perspective from EU member states. She presented how countries have to report the AFOLU emissions and how some of the reporting is changing with the implementation of the Paris Agreement. She addressed the different reporting Tiers and the approaches to defining land use, and how countries are implementing these. Marina's key messages were: i) UNFCCC rules, national definitions and data availability are key elements in the framework of GHG inventory process;

ii) IPCC guidelines provide different methods and factors to assess emissions/removals to be applied at national level on the basis of data and resource availability; consequently large variety of approaches/methods/factors exists in the reported estimates; iii) inventory agencies are open to provide additional detailed information on the estimation process and to update/modify data and methods used as long as consistency with IPCC guidelines and UNFCCC decisions is ensured; iv) any proposal by the EO community in relation to novel approaches/methods to be applied in the verification of the GHG estimates is more than welcome.

The third presentation of Day 1 was given by Frank Martin Seifert (ESA), entitled “AFOLU from Space – The Earth Observation Perspective.” He discussed how the guidance on use of satellite observation in national GHG inventories has been enhanced in the 2019 Refinement: i) for QA/QC and verification through comparison of GHG emission estimates with atmospheric measurement using inverse models (Vol.1); ii) for estimation of GHG emissions/removals from land, through biomass density map for biomass estimation and land cover datasets for identification of human induced land-use change (Vol.4). He then went on to show the various satellite missions that can contribute to the AFOLU sector reporting and showed examples of how these data sets are already used in for instance ESA-CCI, C3S and CLMS. He concluded with outlining the CEOS AFOLU Roadmap, which is currently under development. He stated that we are in a data rich period, a good basis for high quality products, with clear uncertainty levels and consistence over time. We need to think holistically about the integration of EO contributions to GHG and AFOLU.

The discussions after the presentations focused on various aspects, which are summarised below (not in order of importance):

- There is a need to progress from one-for-all solutions to using a combination of data sources, both from satellites and from the ground, to help us answer the questions. Various projects, such as Sen2-Agri, are already pioneering this for the relatively easier agricultural sector.
- There was quite some discussion on the relationship between land cover, land use, and actual emissions. It was noted that the framework that is implemented as part of the Paris Agreement is far less oriented towards the "activity" (use) approach of the Kyoto Protocol. This makes the Earth Observation products, such as land cover data (and change data), potentially very valuable. The discussion about land cover, land use, and actual emissions is not the most important one. In the end we need emission estimates, even though land use is still used for the reporting and therefore still has relevance. Also, land cover is very useful as a proxy for the Carbon content, but land use is needed to estimate the Carbon dynamics.
- While the basic statistics and observations for the LULUCF reporting in the EU Member States represent a wealth of data, these are often of heterogeneous nature and more uniformity for the reporting under the EU is desired and aimed at with the LULUCF regulation and with Forest reference levels. It is not the aim to lose the wealth of basic data, which varies country by country but results from sometimes important investments in these countries, but there is a need for consistent information across the EU and over long time periods. Earth observation and top-down estimates in an integrated system could potentially provide a consistent estimate for all countries for comparison.
- More consistency could/should be developed for emission factors.
- Emission reporting for the AFOLU sector still has large uncertainties, which also vary country by country and are sometimes underestimated. More or less independent estimates could really help to get a better handle on these emissions.
- To better understand uncertainties a scientific approach could be followed by separating in the different components (e.g., fires and other disturbances, above-ground and below-ground). Some of these can be observed; others can only be based

on modelling. But the component-by-component approach would help to better quantify the overall uncertainty.
- While IPCC guidelines are detailed and clear, the implementation by countries can differ. An example that was discussed was the mapping unit for forest cover.

2.2 Day 2

Day 2 of the workshop was again introduced by Gianpaolo Balsamo and Richard Engelen. Gianpaolo showed some recent results from the CHE project both on the global and local scale. Richard then summarized the aims of the workshop again and looked briefly back on the first day.

The first presentation of day 2 was given by Roxana Petrescuy (VUA), entitled "Messages from the VERIFY synthesis on AFOLU flux estimates (CO_2 and CH_4)." She presented the results from a study that has recently been published in ESSD (https://essd.copernicus.org/articles/12/961/2020/), which highlights the importance of reliable quantification of GHG emissions to the latest scientific standards in support of the Paris Agreement. She provided an overview of existing scientific bottom-up data sets for AFOLU sector, and identifies uncertainties related to the calculations of emissions and their sources. The main outcomes were: i) For CH_4 the main differences between NGHGI reports and models are the use of tiers and methodologies (for both emissions and uncertainty calculation); ii) One detected similarity between all sources is the use of emission factors (EFs), as almost all sources make use of the IPCC defaults.; iii) activity data (AD) is shared and often data sources rely on the same basic activity data (FAOSTAT or MS) but regrouping of subclasses is sometimes done using different complexity - Future verification of AD using high resolution remote sensing data (Sentinels) could be an option; iv) For CO_2 and LULUCF sector, there is the need to reduce the gap between inventories and models by defining common definitions in land use reporting. Roxana also provided preliminary results from the first annual synthesis from the VERIFY project. Main outcomes so far are: i) CH_4 bottom-up estimates from agriculture are, in general, within the uncertainty range of the NGHGI data; ii) The main differences are caused by the application of different tiers and methods used in calculating emissions; iii) The top-down ensemble estimates of CO_2 show large variability: regional EUROCOM ensemble mean seems to be the closest to the NGHGI but highly variable; iv) For CO_2 and LULUCF sector, there is the need to reduce the gap between inventories and models by defining common definitions and conventions in land use reporting (e.g. managed/unmanaged land, above/below ground carbon, …).

Lucia Perugini (CMCC) then presented some of the outcomes from the VERIFY network meeting that took place early November. This meeting was organised as part of the VERIFY work package 1 – GHG MRV User Requirements with the objective to interact between national inventory agencies and the scientific community. The workshop was spread over 3 days focusing on CO_2 fossil fuel emissions, CO_2 land emissions, and N_2O and CH_4 emissions. For the CO_2 discussions the main outcomes were: i) Countries are moving to spatially-explicit estimations of forest-related GHG emissions and removals; ii) Prominent motivations: better understand spatio-temporal patterns and for tracking of mitigation activities and related planning/management; iii) Current use and awareness mostly for land use change; less so for biomass maps and forest/carbon models; iv) Most need for "high-resolution" data (i.e., 10-30 m, annual); v) Consistency is key: long-term, national definitions; vi) Sense of limited availability/accuracy/consistency of data sources and approaches ... at the same time limited awareness for some new developments. Also, as some more general conclusions, the following was noted: i) The bottom-up mean agrees generally well with the UNFCCC estimates, but show larger (climate) variability (i.e., ORCHIDEE); ii) The top-down ensemble estimates show large variability and uncertainty; iii) For CO_2 and LULUCF sector, there is the need to reduce the gap between inventories and models by defining common definitions in land use reporting and respect set conventions (e.g. only accounting above ground carbon, only managed land, …); iv) The uncertainty is a fundamental parameter; it is essential to correctly compare emission/removal estimates; v) Verification is an important issue for all

these levels (AD, IEF, emissions/removals) as all the results necessarily need to match; vi) The spatial resolution of current top-down models could be a limiting factor for the application of these instruments for verification purposes; vii) Categories and sectors need to be identified; viii) Dissemination of new tools is important (low awareness of availability of new tools).

The discussions after the presentations focused on various aspects, which are summarised below:

- Bottom-up models for CO_2 emissions from the AFOLU sector still show significant differences. Most of these differences are probably related to the treatment of soil carbon. More work is needed on this topic and where possible, related observations should be more exploited (e.g., http://www.world-soils.com).
- It was noted that bottom-up models and top-down estimates show large annual and interannual variability that is not present in inventories. Should this temporal variability be taken up in inventories as part of the Global Stocktake process (as these can represent also some indirect climate feedbacks)?
- It is important to create consistent long-term observational data records. A lot of work has been done on this already, but more is needed. A combination of different satellites will help to achieve both high-resolution spatial coverage and long-term temporal coverage. It is also important to better estimate the uncertainties.
- Biomass (and related) observations could be assimilated in our bottom-up models, but this is still in its infancy and not easy to do. Horizontal biomass flows by trading is another issue that needs to be carefully addressed in the inventories
- Observations can also help to better understand the spread between the models. Some models do better than others for certain aspects, but worse than others for other aspects. Observations can help to identify these partial deficiencies in the models.
- In CCFFDAS observations are already used to constrained specific parts of the carbon cycle. So far, this has been done at very coarse resolution, but this can be improved.
- The discussion about land use and land classification came up again. For instance, ESA-CCI provides land cover maps with woody cropland and forest. Both contain trees, but different models use different approaches to model these. This also generates differences between the models.
- While land cover preferably needs to be known at very high resolution, this is not necessary the case for land use. Especially within Europe, we tend to know how to map the land cover into land use and land use information. However, this requires careful interpretation of the Earth Observation data in combination with other parameters and can therefore be based on coarser information (both spatially and temporally).
- Significant focus is on Europe, but we should not forget about other areas in the world that are very significant for the carbon cycle and therefore for mitigating climate change. Examples are the Amazon, tropical Africa and Australia. There is a real need to think globally through international collaboration. The RED4Copernicus addresses the GHG emissions from for instance tropical forests in support of UNFCCC's REDD+ initiative for Reducing Emissions by Deforestation and Forest Degradation.
- It is also worthwhile to think long-term. How do we monitor carbon neutrality? Are we 20 years from now in a position that we can monitor anomalies from the carbon-neutral goal?
- For the meeting planned for summer 2021 there are two main topics: i) further connect the Earth Observation and modelling communities with the policy sector (UNFCCC, EC, Member States); ii) progress on the technical requirements to provide added value products. Both discussions should be taken in an international context to ensure efforts are aligned, consistent, and internationally acceptable. It was also noted that products should not necessarily be standardised, and that some diversity is required as well to meet the various user requirements. Use cases could help with that assessment.

3 Conclusion

From the presentations and discussions, it was clear that the AFOLU reporting is complex. Detailed IPCC guidelines are followed but can be implemented differently depending on data availability in countries. Also, uncertainties can be large although they have been significantly reduced over the last decade. There is potentially a wealth of Earth Observation data available and modelling and data assimilation systems can provide complementary information. However, definitions for reporting are often different from what is used in modelling and Earth Observation applications. Land cover data from observations can provide good estimates of the carbon content in combination with empirical static models, but land use is more representative of the carbon dynamics. Also, land use is the focus for the GHG reporting methodology because of the focus on the human activities. In the end, the main output is emissions and both land cover and land use data sets can provide valuable information.

Sector-specific models (e.g., CAPRI (Common Agricultural Policy Regionalised Impact)) are already used (as also recommended by IPCC). But mitigating/adaptive measures influence different sectors and there is therefore a need for integrating the results as well. This is an area where the future Copernicus CO2MVS can play a significant role, which was acknowledged during the workshop.

Bottom-up models still show significant differences, which was attributed to the treatment of soil carbon. Bottom-up models and top-down estimates also show significant annual and interannual variability, which is not captured by the inventories. In all these areas observations can help to improve the models or understand differences between different methodologies.

Not only is a good representation of the various processes within the AFOLU domain needed in the CO2MVS to better estimate fossil fuel emissions, the CO2MVS can also provide added-value emission estimates for the AFOLU domain by combining Earth Observations, modelling and data assimilation in an integrated way. This would be at much coarser resolution than some of the Earth Observation land cover products and reporting methodologies, but the value would be given by consistency and higher temporal and spatial resolution of added-value products for the global domain.

Recommendations for a follow-up international workshop, to be organised by JRC in summer 2021, were given at a high level only. It is important to further connect the Earth Observation and modelling communities with the policy sector (UNFCCC, EC, Member States) and to progress on the technical requirements for providing added value products. Both discussions should be taken in an international context to ensure efforts are aligned and consistent. It was also noted that products should not necessarily be standardised, and that some diversity is required as well to meet the various user requirements. Use cases could help with that assessment.

4 Appendix: Outputs from online discussion platform

To support the discussions, an online tool was used to allow participants to provide written comments. The tool, called Padlet (www.padlet.com), simulates traditional post-it notes. Questions were framed in four different themes and they are listed with the various responses in the sub-sections below.

4.1 Official emission reporting

What are the key variables in terms of activity data and emission factors for the AFOLU sector and its components for reporting (both CO_2 and CH_4)?

- Forest area, tree age classes, dead wood, area of organic soils, groundwater table of organic soils, carbon stocks and their change rates in mineral soils, land use, animal numbers, milk yield, feed composition, animal growth rates, grazing times, practices of manure management and storage, data on liming and urea fertilizer application.

- The main reasons on interannual variability are natural disturbances and harvest level in forests.

What are the current methodologies used for reporting the AFOLU sector to UNFCCC and how could the IPCC 2019 Refinements change the reporting of AFOLU in the future? What are the challenges at Member State level?

- Maybe the challenge at MS level is to agree on one uniform EU reporting - using the same data, possibly EO or an agreed model(s)?
- Within VERIFY we made a survey to ask the inventory agencies on their needs for spatially explicit Forest related GHG flux estimates; The results are helpful for this question: https://forms.gle/rrSH5cUTEEk3LEzA6
    - Some of the results were summarised in the last Workshop with Inventory agencies; see Martin Herold's presentation under: http://verify.lsce.ipsl.fr/index.php/events/verify-second-networking-meeting
- If we all use the same data, it would reduce over-all quality because countries could not use better data sources that are only available at national level. E.g., national soil inventories are sometimes more detailed than European inventories.
    - Consider that agricultural practices and practices of land use are also heterogeneous. That is part of the heterogeneity observed in the inventories (e.g., implied emission factors for manure management presented by Marina, part of that is how much grazing compared to housing is done in cattle farming).

What are the most promising ways to reduce these uncertainties?

- Data collection at country level, including data and parameters needed for emission estimates (e.g., gross energy intake or diet composition for enteric fermentation, management practices for soils carbon stock changes).
- Using the new satellite images, land use changes can be verified.
- Closure experiments including atmospheric EO GHG, EO based AFOLU sector data and inventory information.

What are the most uncertain key categories in the AFOLU sector? What are the main drivers for these uncertainties?

- Example of forest fires? If the positive (sequestered) carbon of x years burns, is it then a negative post? And what if that happens in a base year? [Not sure if under right question]
- Emissions from drained organic soils, because no national monitoring of groundwater levels, which means this has to be modelled
- Forest biomass (because the pool is so huge)
- N_2O emissions from soils because the Tier-1 emission factor is so uncertain
- Organic soils
- Increasing number of wildfires, statistics are not available everywhere and the database is not yet optimal
- Uncertainty calculation itself

What will change for EU member states in the post-2020 reporting regime that will start in 2023, when emissions reporting will no longer follow the Regulation 525 but Regulation 1999 and Regulation 841 for LULUCF reporting, on spatially disaggregated data in particular.

- EU Member States already report emissions and removals from Agriculture sector and LULUCF sector following the IPCC 2006 Guidelines (this is a key challenge for developing countries). For spatially explicit data, almost all countries already report following IPCC approaches and methods for land use and land use changes tracking, at least at net level. To be taken into account that the land unit tracking is one of the possibilities for land spatially explicit monitoring, but not the only one.

- Annual data in a timely manner; "proxy" reporting yr +1, for LULUCF (was not required before), among other things.

4.2 Use of observations

Which variables related to the AFOLU fluxes do we observe directly from space or in situ observations and how do these address the requirements in terms of spatial (measure heterogenous scenes) and temporal resolution (measure change)?

- How strictly do we (have to) separate between anthropogenic and natural?
- Copernicus Global Land Service:
  - land cover changes
  - status of vegetation (and its change over time): through vegetation indices (FAPAR, LAI, NDVI, NPP) and the phenology changes (e.g., start of season, max value, season length, etc.)
  - burnt areas (this can be obtained over the various land covers or the land cover change areas)
  - resolutions are 100m for global land covers 1yr inter, 300m for the vegetation products - global 10day intervals; some of this will be available at 20m resolution in the (near) future
- We might want to use global EO products like from Global Land reserved for the CO_2 Monitoring and Verification Support Capacity, while the AFOLU bottom-up inventory uses national, spatial data from different nature (IACS, N2K, ...). It is important to make optimal advantage of all data streams.

How can we relate to the impact of certain climate effects, such as droughts or flooding?

- Land classification and national definitions: how can EO contributes to key element of LULUCF inventory?
- Space-based observations of solar-induced fluorescence (SIF) can support identifying such effects.

What other variables can we observe from space or in situ observations to help constrain the AFOLU fluxes?

- Copernicus supporting observations. AFOLU can be supported from imagery missions like Sentinel-2 and Sentinel-3, and further amended with information from solar-induced fluorescence (SIF) from current and future satellite missions.
- Water content in soil with regard to rewetted areas
- Meteorological conditions such as strong wind might be directly related to one of the major forest disturbances in Europe.

4.3 Use of modelling

How do we handle AFOLU and fossil fuel emissions in our land surface models, so we can separate fossil fuel emissions, or more generally anthropogenic emissions, from natural variability?

- A harmonization of basic activity data (i.e., input data in modeling) is needed, by comparison with the data used, at country level, in GHG inventory reporting, sector by sector, category by category.
- Currently, fossil fuel emissions are mostly prescribed using monthly mean estimates; maybe adding the synoptic, daily variability in the fossil emission, would help when using the sum of AFOLU and fossil fuel emissions in transport models.
- Not sure I understand the "fossil fuel emission in land surface models" can you explain? FF emission comes in gridded sector specific form, so it can be traced? of course the biosphere (uptake) considers all CO_2 in the atmosphere equal.
- Getting also the natural emissions better quantified?

- The separation of fossil fuel emission and biogenic emissions from both AFOLU and natural sources can be achieved through the inclusion of representation of the respective processes specific for the individual sectors into the top-down inversion approach (CCFFDAS).

Can we use sector specific models, such as for crops or forest only? What is their further development challenge?

- Sector specific models (e.g., CAPRI) are used (as also recommended by IPCC). Integration of all sectors is what DG CLIMA is now more interested in (in view also of mitigating/adaptive measures that have effect on different sectors). Work is ongoing for this (e.g., at JRC) but remains challenging.
- Crop models that capture the effect of management in the SOC would be indeed useful to track the effect of the common agricultural policy within the LULUCF reporting sector at EU level. However, activity data (spatial information on where the activities are implemented) need to be improved/provided.

What are the main challenges for current Dynamic Global Vegetation Models? How different are they and what is the potential added value of model ensembles?

- At least: i) representing the impact of land management diversity on C budgets, ii) biotic effects, iii) legacy of past LCC (especially with respect to soil C dynamic), iv) lateral C flux dynamic
- Sub-question: Are DGVM models at appropriate spatial resolution for users, mature enough for operational implementation? if so, just for EU or also Global?

Whereas for fossil fuel CO_2 emissions, one can use co-emitted species as indicators, which variables would you be using to identify effects of the AFOLU activities (solar-induced fluorescence, …)?

- It's not my field, but I would think that with the rapid increase in resolution and quality of the LU data from space (shown yesterday) instead of co-emitted species; "co-happening" observed change in LU could provide some real indicators backing-up certain trends.
- Meteorological parameters that are related to the seasonal variability of AFOLU? Just a suggestion.
- For AFOLU activities variables such as SIF, VOD, FAPAR in combination with land cover (and land cover change) can be used as indicators.

4.4 Role of Copernicus CO2MVS

Is there a role for the Copernicus CO2MVS capacity to provide added value to the current reporting?

- Define current! Next year? probably not. in 5 years – yes, I would think so. Uncertainties are large so additional constraints will be very welcome.
- Provide a system approach bringing together top-down and bottom-up estimates
- Allow users to build use of CO2MVS into their processes, with confidence that this will be sustained in the long-term
- Yes. the CO2MVS capacity can provide consistency checks on the current reporting by including additional observational information from both the atmosphere but also from multiple terrestrial measurement systems.
- A step towards integration of measurements from different sensor concepts into terrestrial biosphere models is taken in ESA's Land surface Carbon Constellation study (optical including FAPAR and SIF, active and passive microwave).

How do we reconcile reported AFOLU emissions with (high-resolution) gridded AFOLU products from Earth observation, models, and inverse modelling?

- We still need to clarify if AFOLU integration in CO2MVS, for internal needs of system, is consistent with needs of end-users in AFOLU sector. If there are different requirements, then they need to be internally consistent
- Combining EO data with models and inverse modelling, top-down, can be achieved through an integrated data assimilation approach that includes a representation of the processes behind the AFOLU emissions (Carbon Cycle Data Assimilation System) and can thus consistently exploit terrestrial and atmospheric observations.

To what extent do we need to account for the AFOLU sector within the foreseen Integrated System approach of the CO2MVS anyway?

- Yes, CO2MVS should account for AFOLU within data Integration system to provide internally consistent emission (and sinks) across all sector required for reporting

Can the CO2MVS capacity for instance contribute to the new LULUCF reporting from 2023 onwards and new wetland CH_4 reporting from 2026 onwards under the EU LULUCF Directive?

- For LULUCF sector, the EU 841/2018 Regulation is not yet driving a dramatic change, in term of GHG reporting. EU MMSS already report all the IPCC land use categories and related emissions/removals. However, in the post 2020 reporting, the LULUCF numbers will be subject to a much stronger review process because the LULUCF sector is taken up as target sector for the 2030 climate targets.

Forest emissions/removals still show significant differences between reported and modelled estimates. Can Earth Observation provide an additional constraint, or will this have to be determined via the Forest reference levels?

- Not sure what is the link between the Forest Reference Levels (assessed on the basis of GHG inventory data and projected data following the LULUCF regulation rules) and the EO. can you explain this issue?
- I think the answer is yes if you look on the longer time series. If we have 5-10-year consistent data it will really help

Can top-down methods give us a better idea of the AFOLU sector? Does this differ for CH_4 and CO_2?

- Yes, clearly differs because for CO_2 the large source + large sink really complicates the issue. For CH_4 it is mostly about source term; much easier (but still difficult).
- Top-down methods for CO_2 have shown to provide key information at global scale even if the land / ocean partition is still an issue; then when going at regional scale the challenge is much larger but maybe for the trends, we can have already important information for the AFOLU.

Document History

Version	Author(s)	Date	Changes
V0.1	Richard Engelen (ECMWF)	07/12/2020	
V1.0	Richard Engelen (ECMWF)	04/01/2021	Included most of the corrections and suggestions from the reviewers.

Internal Review History

Internal Reviewers	Date	Comments
TNO	15/12/2020	approved with comments
G. Janssens-Maenhout (JRC)	18/12/2020	I very much appreciated the workshop incl. the very appropriate use of the Padlet tool. I support fully this report as summary. I would suggest eventually to include a table with those EO data sets, those models, those statistics which are considered important for the AFOLU CO_2 emissions inventory.

Estimated Effort Contribution per Partner

Partner	Effort
ECMWF	1
Total	**1**