Joint Programming Initiatives

"*Connecting Climate Knowledge for Europe*" (JPI Climate)

&

"*Agriculture, Food Security and Climate Change*" (FACCE-JPI)

Joint online workshop

"Land-based greenhouse gas (GHG) emissions/removals and analysis systems"

14th April 2021

Workshop Report

April 2021

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Executive Summary

In 2010, the European Council launched the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI) with the objective of “stimulating collaboration between members states, to provide coherence in research programming”, to address the societal challenges of food security and climate change impacts and develop approaches to mitigate greenhouse gas emissions. FACCE-JPI comprises twenty-four member states, associated countries and one-third country (New Zealand) who are all committed to building an integrated European Research Area with the aim of addressing the interconnecting challenges of climate change impacts and food security. To date, FACCE-JPI has funded over 120 projects in mainly new established collaborations, involving approximately 900 project partners from over 500 organisations. This has given rise to 600 high scientific quality publications.

Since its inception in January 2011, the Joint Programming Initiative "Connecting Climate Knowledge for Europe" (JPI Climate) aims to bring together “existing and developing new excellent scientific knowledge that is needed to assist practitioners to adequately transform society towards climate resilience”. The fostering of connecting various scientific disciplines, enabling cross border research and increasing science practice interaction facilitates European efforts to tackle the societal challenge of climate change. To date, JPI Climate has nineteen member countries and the European Commission. Additional countries such as Brazil, China, India, Japan and Qatar are working collaboratively with JPI Climate in the context of the joint Call for Climate Services Collaborative Research action on Climate Predictability and Inter-regional Linkages, together with the Belmont Forum. Some of the current activities of JPI Climate include the implementation of various European projects (e.g. SINCERE, AXIS, ERA4CS), as well as the development of strategic Knowledge Hubs and the co-organisation of the 5th European Climate Change Adaptation Conference (ECCA 2021). This conference will focus on bringing adaptation solutions to life, by inspiring climate adaptation action today for a resilient future.

With the objective of identifying and considering research needed in order to bridge gaps between the top-down analysis of GHG emissions and removals by managed terrestrial sinks (land) and the analysis provided in national inventories, JPI Climate and FACCE-JPI organised a joint workshop online, held on 14 April 2021.

This document provides a report of the workshop, including its presentations, discussion points and identified actions. The next steps identified include:

Step 1:	Follow up meetings between JPI Climate and FACCE (Q3 2021); FACCE SAB meeting (April 2021); JPI Climate GB meeting (June 2021)
Step 2:	Aim for an open dialogue process with Policy makers (national and international) and arrange a scientific meeting in Q3/4 2021;
Step 3:	Outline of a Joint meeting Q3/4 2021 to identify areas of research priorities and investment, including around model comparison and collection and measuring of inventory related data;
Step 4:	Reach out and engage with other communities, such as industry, private and land use sectors (Q3/4 2021);
Step 5:	A Joint Call 2022 with the objective to provide more accurate and consistent data sets over time and space & harmonisation of these with model analysis as well as to enable intercomparison of models and improve the use of available data sets. The organisational details of the call should also be discussed and agreed between both JPIs.

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List of Abbreviations

Term	Meaning
AFOLU	Agriculture, Forestry & Other Land Uses
CFR	Common Format Report
CHE	CO_2 Human Emissions
JPI Climate	Joint Programming Initiative "Connecting Climate Knowledge for Europe"
DGVM	Dynamic Global Vegetation Model
FACCE-JPI	Joint Programming Initiative on Agriculture, Food Security and Climate Change
GHG	Greenhouse Gas
GST	Global Stocktake
IAMs	Integrated Assessment Models
ICOS	Integrated Carbon Observation System
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land-use Change and Forestry
NBS	Nature-based Solutions
NDCs	Nationally Determined Contributions
SPM	Summary for Policymakers
UNFCCC	United Nations Framework Convention on Climate Change

1. Introduction

The main goal of the Paris Agreement in 2015 was to limit global warming well below 2 °C, to pre-industrial levels and to pursue efforts to limit the increase to 1.5°C. The challenge is an arduous task and the success of the agreement critically depends on the implementation of climate policies at the national level. It requires the commitment of all countries and the various sectors, particularly agriculture and forestry. Mobilising stronger and more ambitious climate action is needed to achieve the goals of the Paris Agreement. Land is both a source and sink of GHGs and important in terms of energy, water and aerosol exchange between the land surface and atmosphere. Ecosystems and biodiversity are susceptible to ongoing climatic events (i.e., extreme rainfall, drought, flooding, etc.) to varying extents. An IPCC Special report on climate change, desertification, and degradation, sustainable land management, food security, and GHG fluxes in terrestrial ecosystems states that global models estimate net CO_2 emissions of 5.2 ± 2.6 $GtCO_2$ yr^{-1} (likely range) from land use and land-use change during 2007–2016. These net emissions are mostly due to deforestation, partly offset by afforestation/reforestation, and emissions and removals by other land use activities. Initiatives such as the "4 per 1000" aim to increase carbon stocks in soils as a compensation for anthropogenic GHG emissions. However, to be realised, different sectors of society will need to stimulate and coordinate better communication between scientists, businesses, public and private enterprises, policymakers, and the public. Land management practices that are sustainable can contribute to reducing adverse impacts of climate change on ecosystems and societies. To this end, JPI Climate and FACCE-JPI recognise the importance of land use and its management in climate actions and have implemented various research activities that serve to increase the common impact of European research on society and inform policy.

Research investment in improving GHG inventories has been implemented throughout Europe. This reflects the commitment made under the UNFCCC and its Kyoto Protocol and the need to improve emission factors uses and activity data in order to reduce uncertainties. National GHG inventories must comply with the IPCC quality criteria of transparency – i.e., complete, accessible, and timely documentation, completeness of anthropogenic GHG sources and sinks, consistency in time and space, comparability between countries, and accuracy (IPCC 2000). They should, as far as possible, reflect real-world activities and associated emissions and removals. Hence national inventories need to be sufficiently detailed to capture policy interventions and measures designed to reduce emissions or enhance removals. Projects such as the Horizon 2020 VERIFY and CHE (CO_2 Human Emissions), as well as follow-up activities such as the COPERNICUS project 'CoCO_2' have advanced these analyses. The challenge is closing the gap on analysis provided by inventories and analysis from large scale models, including Integrated Assessment Models (IAMs). There needs to be an alignment and linkage between inventory analysis and analysis provided *via* large scale models. Against this background, this expert workshop has been convened to explore the state of play on these issues and how and where challenges may be further addressed through research.

This report contains the proceedings of the workshop held online on 14 April 2021. The aims of the workshop were to identify and consider research needed to bridge gaps between the top-down analysis of emissions and removals by managed terrestrial sinks (land) and the analysis provided in national GHG inventories.

Workshop Programme

The one-day workshop was organised online by the secretariats of both JPIs and included four presentations and an open discussion session.

The workshop was opened by Frank McGovern (Chair, JPI Climate) and Jean-François Soussana, (Vice-Chair, FACCE-JPI).

Jean-François Soussana provided an overview of FACCE-JPI and their many activities. FACCE-JPI promotes the integration and alignment of national research resources in Europe under a common research strategy, to address the diverse challenges in agriculture, food security and climate change. FACCE-JPI brings together 24 countries committed to building an integrated European Research Area. Joint actions of the FACCE-JPI include Knowledge Hubs (MACSUR 1 & 2, Sci-Pol Hub, Food and Nutrition), the Knowledge Network on Sustainable Intensification and the Thematic Annual Programming Network on Soil. Approximately 50% of joint actions have been developed in cooperation with other international/EU initiatives (2012-2017). Regarding calls, FACCE-JPI has implemented a multi-partner call (with Global Research Alliance countries), a call with the Belmont Forum, BiodivERsA and with the Water JPI (WaterWorks 2015). FACCE-JPI has given rise to 5 ERA-NETs with around 100 projects (in total) to date, as well as being at the origin of the European Joint Programme (EJP) Soil.

The updated Strategic Research Agenda (SRA) 2020 outlines how FACCE-JPI will "continue to align and co-design research and deliver knowledge for addressing the challenges of sustainable and resilient agricultural production systems integrating the interdependent climate system, food system and ecosystem". The four core themes outline a "path towards an agricultural sector that respects the planetary boundaries, preserves and encourages biodiversity, reduces emissions and inputs, embraces new approaches such as agroecology, and at the same time provides a sufficient and healthy diet".

This SRA includes 4 themes:

- Theme 1. An agricultural sector that contributes to climate neutrality
- Theme 2. Sustainable and resilient agriculture
- Theme 3. Nutrition-sensitive agricultural production for food security
- Theme 4. Trade-offs and synergies between food production, ecosystems and climate

Other initiatives like the FACCE-JPI project "Wheel" serve as an interactive visualisation tool to valorise FACCE-JPI research on food, agriculture, and climate change.

FACCE-JPI has initiated a multinational science-policy knowledge forum as a pilot to bring the science and policy together, to strategically design the response to climate change adaptation and mitigation challenges in the agri-food sector in Europe. The main objective is to "establish a European forum with model-generated knowledge synthesis for evidence-based policy support to achieve carbon neutrality by 2050, adapt to climate change and understand synergies and trade-offs in achieving these targets".

The Horizon 2020 CIRCASA project started in November 2017 for a duration of three years. The project is aimed at developing international synergies concerning research and knowledge exchange in the field of carbon sequestration in agricultural soils at European Union and global levels, with the active engagement of all relevant stakeholders.

Presentation 1: "Framing"

María José Sanz Sánchez *(Co-Chair of JPI Climate Transdisciplinary Advisory Board)*

The presentation provided context to the reporting obligations of European countries under the UNFCCC that are primarily to demonstrate their compliance with their targets under the Kyoto Protocol and investment in research to improve their GHG emissions inventories.

The IPCC GHG Inventory Guidelines were put forward as a basis to promote transparency, accuracy, completeness, consistency, and comparability across inventories of countries under the UNFCCC. Currently, under the Paris Agreement, GHG inventories continue to be the key instrument for countries to show progress in their mitigation efforts under their NDCs. Recent efforts in GHG reporting reached closer levels between developed and developing countries, in quality and regularity as per the Transparency Framework. However, international reporting is not the only reason for the need for national GHG inventories and to seek its continuous improvement. GHG inventories are central to policy, through informing its implementation and for tracking progress in achieving targets at a domestic level. It is essential that the inventories are sufficiently detailed to capture policy interventions and other measures that are designed to manage emissions and removals. Therefore, it is imperative to support the governments in the development of their climate change strategies, as a basis to improve their projections and scenarios and overall raise their ambition realistically.

The Paris Agreement mandates a periodic Global Stocktake (GST) exercise to assess a country's collective progress towards meeting its long-term goals. This represents an opportunity to collectively discuss/debate and assess different inputs beyond country reporting at a global scale. GST could promote as far as possible the improvements of the GHG globally and better harmonisation with top-down analysis provided *via* Earth systems models and Integrated Assessment Models (IAMs). In this context, there is room for improvement and development. This is becoming more important as inventory systems are evolving in the context of advanced systems for top-down verification of emissions and removals, as well as devolving into regionalised and local tools to inform climate plans and strategies.

Why would we like to focus on the AFOLU sector?

LULUCF measures represent about 25% of the emissions reductions pledged by countries in their NDCs in the Paris Agreement. The global scientific community's most recent land-based and NBS mitigation estimations lead to highlight and recognise the sector as a potential key for reaching the Paris Agreement's goal, which implies net-zero emissions by 2050 may be reached. There are still major discrepancies between the aggregation of bottom-up inventory data and top-down global models (Grassi et al 2018). However, the fact that global data sets (such as remote sensing products by COPERNICUS) are improved substantially and are accessible to both communities (modelers and inventory compilers) will partially close the gap. Most importantly, they could improve the activity data in the inventory side while providing more complete and consistent data sets for modelling. Inventories and their needs generated further development of methodological guidance (IPCC, 2019), as well as gathering relevant information to improve the GHG emission factors of other than forestry in relevant production systems (LIFE MEDINET) and systems of practices.

Summary

Inventories are essential for:

- Reporting of the Paris Transparency Framework, where they are mandatory and must be compiled compliant with the IPCC Guidelines for GHG Inventories (mandatory in the 2006 Guidelines towards the use of the 2019 Refinement to these Guidelines).
- Domestic use for planning and evaluating progress and impact of national regulations, and in many cases represent the only space where sectorial departments share and where data is pooled together, showing links and finding inconsistencies that can be then addressed.
- Inventories include not only estimations of the emissions and removals, but also very valuable background information on activities that cause emissions and removals that are obtained in many cases at very disaggregated level and can be used as well as the final estimates as inputs in the modelling, such as pathways modelling. They are also relevant to understand the drivers of the trends.
- Global assessments by IPCC benefited from the information provided by inventories, by improving input data to models or as a verification tool. But, also to complete their input data, it becomes urgent that the GHG inventory data is well understood and better used (and therefore not to be misused).

On the other hand:

- The collection of global datasets, in particular from Remote Sensing and the Systematic Observation community, is currently a key source of data for both top down global and regional estimations (often using IAMs) and bottom up National GHG inventories and their aggregations at regional level (such as the EU inventory).
- New services are emerging in this context (Climate Services) that need to be "serving" both communities, allowing for the improvement of GHG Inventories and regional/global monitoring.
- First steps to move towards better, more accurate and consistency over time and space estimations to ensure the proper use of available and increasing data sets. However, it is prudent to acknowledge that the objectives and use of estimates may differ, and that discrepancies in the estimations will appear and need to be understood if we want progressive merges in top down and bottom-up exercises. Both will remain necessary. Therefore, the different communities involved will need to collectively identify topics for improvement and close the estimations gaps as far as possible while respecting their roles and respective scales of contribution.

Question 1. Regarding the FACCE-JPI community, many people are working on mitigation action that is not currently reflected in national inventories: how do we implement changes not captured by modellers?

Question 2. How can we align these inventories at a national/global scale- with those at farm scale in terms of emissions with food value scale or biomass value scale expressed at life cycle assessments (LCAs)?

Presentation 2: State of knowledge: relevant developments since the IPCC Reports (2019)

Keynote by Giacomo Grassi *(Joint Research Centre-The Italian Institute for Environmental Protection and Research (JRC-ISPRA))*

The relevant updates since the IPCC Reports 2019 were presented. There have been many other relevant updates, however this update is relevant in the context of this meeting in aiming to bridge gaps between top-down global models and national GHG inventories. The presentation is based on a paper that will be published soon in *Nature Climate Change*. The paper, titled "Critical adjustment of land mitigation pathways for assessing countries climate progress", focuses on reconciling the current mismatch between estimates from integration system models and country inventories.

Context

To achieve the requirements of the Paris Agreement to hold global warming to well below 2°C requires reaching a balance between anthropogenic emissions and removals in the second half of the century. Reaching a balance means that since not all emissions can be brought to zero, remaining emissions will have to be compensated by extra removals, thus the forest is the main tool where we must manage removal at the scale needed. It is hoped that carbon capture storage will come as soon as possible.

The car analogy was used where the driver of the car is the policy maker. The National GHG inventory provides key information to climate policy and for assessing compliance to the Paris Agreement like the car dashboard for the driver. IAMs describe the future GHG emission pathways to reach specific temperatures. Like the navigation system provides routes to reach specific destinations. Once a destination is selected, the driver uses the navigation system to check that he/she is on track, like policy makers may use IAMs to assess the collective progress towards the Paris Agreement. It is important to acknowledge the expected roles, and the global models are essential to drive the policymaker to a right direction and to arrive on time, however, they will never have to forget that the policymaker has his own car dashboard which is the main source of information. The navigation system will be used to assess their collective progress and will be accessed through the GST that will take place every five years from 2023. The technical change will start in 2022 and will assess the collected progress toward the truly great target of 2°C in the light of best available science. Inputs to the GST include GHG inventory data from aggregated countries and IPCCIPCC AR6 and other scientific data. The data will be compared to assess the future ‘gap’ that should stimulate increased climate ambition. The GST requires comparability.

The Problem

There are large gaps between IAMs and National GHG Inventories (NGHGI) on land use CO_2 fluxes. The possible reasons for this gap include (1) simplified and incomplete representations of land use in global models (2) inaccurate or incomplete estimation of land fluxes in NGHGI and (3) conceptual inconsistencies between IAMs and NGHGI data in defining anthropogenic CO_2 sinks. There are marked differences, in particular for the removal data. The reason for this discrepancy lies with the source of data. IAMs tend to show direct human induced effects, whereas the NGHGI will show direct human induced effects and indirect human induced effects (natural effects). Different forest management areas are also included in the NGHGI data that IAMs do not select. Therefore, different approaches to identify anthropogenic CO_2 adopted by two different communities will show varying results. One approach is not better than the other, both have validity and limitation. It is suggested that countries include environmental change on a much larger 'managed' area. A country may report emissions as anthropogenic whereas a model may report emission as natural. It is essentially a labelling issue. The gap in global land use CO_2 fluxes by IAMs and NGHGI is like if a navigation system uses 'miles' and the dashboard 'kms'. Different land use CO_2 fluxes may hamper an accurate assessment by policy makers of the collective climate progress. This issue has been acknowledged by the IPCC in the Summary for Policymakers (SPM) of the Special Report 1.5°C (2018) and the SPM of the Special Report Climate Change and Land. It has also been discussed during plenary sessions at the UNFCCC (COP 25, IPCC SBSTA event 2019).

The solution

Using the car analogy again, to change the NGHGI based on consolidated IPCC guidelines and UNFCCC is as impractical as changing the car dashboard. Changing the unit of the navigation system to match the dashboard would be easier. Likewise, translating IAMs results to make them more comparable with NGHGI would be a pragmatic short-term fix to ensure a more accurate assessment of the collective climate progress. Since IAMs only look at direct human induced effects on managed land and Dynamic Global Vegetation Models (DGVMs) look at indirect human induced effects on managed and unmanaged land, if you sum the IAMs and DGVM models you have an amalgamation of data for managed land only. Translating IAMs results into estimates comparable with GHG inventories will result in a perceived strengthening of the required global mitigation efforts by countries.

- It is not suggested that including indirect effects is desirable: by including them in IAMs pathways, we cancel out their impact in the NGHGI -IAM comparison.
- The authors' approach is not the final method, but a short-term pragmatic fix to ensure comparability between global models and countries at the global stock take.

Many aspects need to be improved:

- Our approach works at global/regional level, but more work is needed at country level.
- Updated projections on forest sink with a model ensemble.
- The effective reconciliation ensured by our approach may hide other underlying uncertainties which compensate, i.e., inaccuracy, incompleteness in both IAMs and NGHGIs.

Question 1. How well understood is the supposed CO_2 fertilization effect? does it take into account elevated temperatures that would inevitably accompany higher concentrations of CO_2?

Question 2. What about the age dynamic effect of forest, will you look at this as an anthropogenic effect linked to management? With IAMs we overestimate the fertilisation effect and underestimate the age dynamic effect which may confuse the natural and the anthropogenic effect, do you think this may happen? Is the age dynamic effect an anthropogenic effect, linked to management?

Question 3. In which other systems can this happen in relation to soils? Could we have the same bias between IAMs and NGHGI? Has similar work been done to evaluate the discrepancy between IAMs and NGHGI for non-CO_2 agricultural greenhouse gases?

Question 4. What are the messages that should be taken from the presentation that can be shared with national and international modellers?

Question 5. Was the introduction of forest reference levels within the EU causing further misalignment and misinterpretation between what comes from national inventories and IAMs? Can we expect that the land sink will continue to follow global emissions (removing app. 30%) also considering saturation and the vulnerability of forests due to climate change?

Ongoing research: CoCO_2/ICOS and current challenge areas

Presentation 3: Top-down inversions and inventories reconciliation

Keynote by Philippe Ciais *(Institut Pierre-Simon Laplace (LSCE)*

This presentation provided an overview of how top-down atmospheric inversions can be compared with bottom-up inventory estimates of emissions and carbon removal. Counting is performed based on energy use and emission factors, activity data for emissions and on the ground inventories for biomass production. Currently in several countries, there is also networking regarding the monitoring of the slow changes in soil carbon. The idea that was promoted by JPI Climate in Dublin was to use observational data and institutional networks like ICOS (Integrated Carbon Observation System), within atmospheric inversion approaches to see how the two approaches compared to each other, and what is more interesting scientifically, and if we see differences and what are the reason for those differences?

It is known how inversions proceed and the idea is to measure the concentration gradients on both sides of the source of the carbon sink. These gradients are related to the activity, but are also related to the winds, and for this we need 3 dimensional models such as the deposit transport model to model the signal of fluxes of sources of carbon sinks into concentrations. In practice the systems used by the community are becoming quite complex because we are using regional or global atmospheric transport models which are fed now by in situ stations. The in-situ data are very accurate to track the gradients needed to quantify fluxes. Satellites offer the big advantage of having global coverage, but still the observation from satellites is relatively sparse for two reasons. For the fall from CO_2 for instance, there are no images yet, therefore, there are only small tracks over here, and more importantly when there are clouds, with the current technology used by satellites there are no concentration measurements. The most extensive set of atmospheric inversions available were compiled thanks to the effort of the community in the Global Carbon Project.

Introduction of inversions comparisons:

Table 1. Inversion comparisons

CO_2: 6 in-situ inversions Same prescribed fossil fuel emissions: only the land flux is optimized. 1979-2019 2014-2019 = 6 $COCO_2$ inversions CH_4: 17 inversions Separation of sectors in priors in most of them 2000-2017 = 9 in-situ inversions & 2 combined inversions 2009-2017 = 8 satellite inversions (GOSAT) N_2O: 3 inversions 2000-2017 = 3 in situ inversions 2009-2017 = 8 satellite inversions (GOSAT)

National inventory communications are very diverse, and each country submits their data through a common format report (CFR). The CFR contains many sectors, and to compare, the information is aggregated by sectors, particularly to separate natural and anthropogenic emissions, because inversions work on the totals. To match inventories, data is grouped into super sectors as the information included in the report is too fine to measure inversions independently.

The National inventories submitted to the UNFCCC include National communications and Biennial update reports. All information received is digitized. Reviewing the data shows the disparity between reporting between countries. There are overestimating differences in the way the different sectors are reported. Different data sources and lack of reporting can lead to vast differences in the inversion totals of CO_2. It is not normal that fossil CO_2 emissions are very different between inversions and UNFCCC. The fossil CO_2 are prescribed as fixed maps in the inversions. Differences may occur because of slight differences in totals. If there are differences, it is because of inversions interpolation of the fields (perhaps also in the post processing of gridded inversions data with coast lines).

In relation to CO_2 – Land flux (sink = negative values), UNFCCC only covers managed lands whereas inversions cover all lands. Regarding land sink data, net long flux show emissions in oxidized environments such as rivers and updates from soils in forests. There are two main traits in the data, (1) there is more year-to-year variability in atmospheric values compared to the inventory., the reason being inventories are made of slow cycles and an integrated value of the flux can be viewed even if they are reported on a yearly basis. (2) The atmospheric impact of climate advance is driving the anomalies. Regions such as Russia and EU have a greater atmospheric (CO_2) uptake than reported.

In relation to CH_4 – total anthropogenic Flux (in-situ inversions) shows that there is a large natural flux of the CH_4 component i.e., (wetlands in the USA and Russia) showing higher atmospheric values. Any error we would make wrongly separating this natural component of what we think it is and extracting the anthropogenic emissions from the inversions would lead to an uncertain comparison. There is a good agreement between the mean of the inversions and the trend and mean of the inventory in groups of countries like the EU or Germany. In other countries like the USA and China, it shows systematically that the atmosphere had higher emission levels than what was reported.

To resolve discrepancies, the TROPOMI imager was implemented. With project partners, imaging was exploited systematically for every plume of CH_4 which is seen in the atmosphere when the satellite passes over, allowing to see hotspots of pollution. The minimum detection level of a big leak that can be captured is 50 ton per hour. It can be added to compare the kind of infraction that the inventory may be missing. This may help to reconcile the unexplained differences between bottom-up inventories and bottom-down inventories. This approach can also look at different sectors within countries and possible pollution sources. Comparisons were conducted for all satellite net fluxes and N_2O net fluxes and the countries who are the biggest emitters of N_2O to the atmosphere. The inventory of emissions can be used to track countries. The relationship between CO_2, CH_4, N_2O emissions trends were analysed. The trend shows that the countries with the largest GDP tend to be the greatest emitters. There is a good match between the atmospheric base estimates and the net removal, with Russia being the exception. This is perhaps because Russia has a lot of unmanaged land. This unmanaged land may contain a large amount of carbon that may not be counted by the current scheme of inventories.

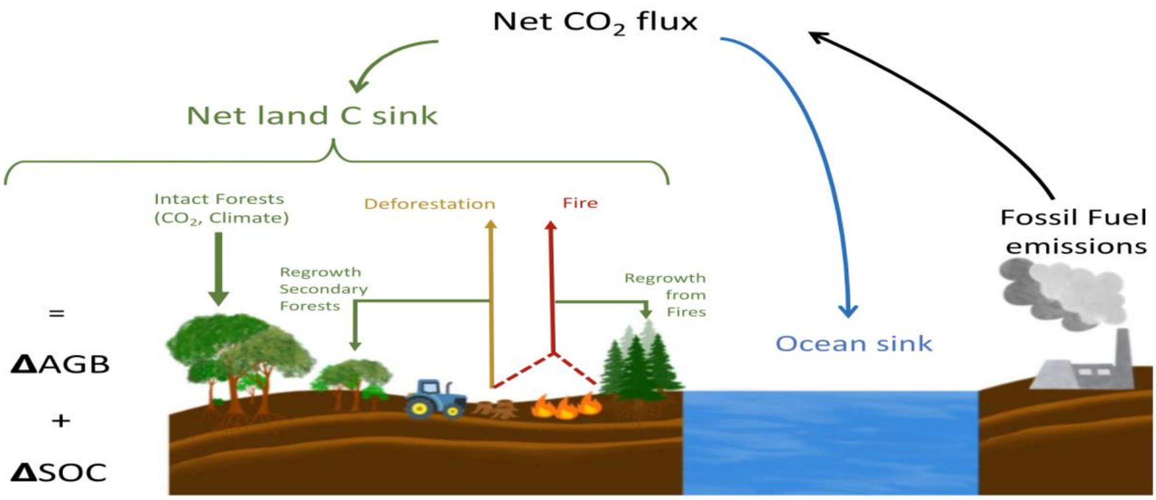

Fig. 1 How the net land carbon sink will be attributed to intact forests, deforestation (ESA CCI Land Cover change), fires (ESA CCI Fires) and regrowth. The net CO2 flux and ocean sinks will be provided by inversions based on situ and satellite CO2 fluxes (ESA CCI GHG).

Figure 1. Net CO_2 Flux Schematic

A proposed future study on the Net CO_2 Flux was introduced. Figure 1 shows the contribution of the net CO_2 flux balance. There is a lot of data that allows calculation of the amount of carbon loss through deforestation and burned area (fire). There is some intersection between the deforestation and fire as they happen in tropical countries. The amount of carbon loss through deforestation and fire is seen through new biomass maps. The two fluxes, which are the recovery after deforestation and of the fire can be calculated. This is possible because there is available disturbance data through Landsat 8 (30 years of data) and the biomass H curve makes it possible to derive from that calculation. Thus, using a very simple but special explicit bookkeeping model we are trying to reconstruct year by year and region by region or pixel by pixel, how much biomass is regained after a fire over the last 30 years and how much biomass is regained by secondary forest which escaped through deforestation. In principle as a residual, we could deduce the rest, which can be degradation and that is easy to observe. Secondary regrowth can be secondary forests from deforestation and fire. The sum of fluxes can be compared with new products such as biomass changes.

Question 1. What is the difference between fossil CH_4 and biogenic CH_4?

Question 2. How do you differentiate the carbon balance in the grasslands?

Question 3. Regarding the lateral transfers, we started to combine for example input and output models on commodity straight and translating that into CO_2. We need an exercise translated into land footprint to understand how the land use is changing since 1964 to 2014 with all the communities in the country, so how would you combine this type of information that comes from another academic arena with what you are doing?

Question 4. Regarding the CO_2 land sink data, do you not include the lateral fluxes or wood harvest?

Question 5. Are there any other emerging areas with high input that can be used for example in food systems and out culture management?

Areas for development and Open Discussion Session

Hayden Montgomery (Global Research Alliance on Agricultural Greenhouse Gases - GRA) kicked off the panel discussion and expressed interest in being part of the process, as a representative from the GRA. There are 64 countries involved in this network and the focus is on agriculture, not forests. However, there is some work on agroforestry. The efforts of the countries and partners involved are intended to better quantify agricultural GHGs, which include the soil carbon, and to develop mitigation options right through international collaboration. The focus is to support the NDCs process of members and, obviously, the greater demand for data and quality of data that developing countries must report under the Paris Transparency Framework.

Looking at the membership of FACCE-JPI and JPI Climate, it accounts for only approximately 8% of agricultural emissions made up by the members of those two joint programming initiatives. Therefore, to make a global impact, we should consider how many other countries we can bring into this effort, so that the work done is able to be used by those other economies with significant agricultural emissions. Projections of significant growth will be seen in emerging economies such as Latin America, Asia and Africa, even if these regions are not currently huge contributors in absolute terms. There is a huge interest in how a more concerted effort by both the remote sensing community and the bottom-up field scientists' community could help us improve the timeliness and quality of reporting of both non-CO_2 greenhouse gases from grasslands and animals that graze them, and the carbon side of things. An area of interest is remote sensing. We are trying to assess remote sensing in most regions of the world to better characterize grassland or range lands globally in terms of tonnage of dry matter, standing biomass and the quality of the biomass in terms of its digestibility, energy content, and protein levels, which is extremely important when trying to calculate enteric methane and nitrous oxide emissions from animal excreta deposited on pastureland. Most countries would report using defaults and there will typically be a single value for an entire year or digestibility for protein content. It is imperative to collate temporal accuracy precision on the changes and pasture quality throughout the year. This is particularly important in climates that have more variability, such as tropical climates, which show huge change and protein content and adjustability. In this context, it will be important to estimate fermentation emissions and nitrous oxide emissions.

The IPCC methodology guidelines show that any change in digestibility show an increase of at least 2 to 4 times on the emissions calculated. Therefore, it would be of huge value and it will require not just the remote sensing community and satellites with high resolution, but good ground truth data to validate that and work out those algorithms that can translate imagery or other information into useful data. It would be useful both for national level and inventory compilers, and ideally for decisions to be made or better decisions to be made by those people managing the land. If it would be possible to detect animals on the landscape with some degree of confidence, obviously there is some sensitivity, however, at least in aggregate terms that would be a huge benefit because there may be a way to help us provide an overall constraint to the bottom up estimation of livestock emissions coming from managed land.

The other aspect is soil carbon. It is still difficult to measure soil carbon stocks from satellites, however we can improve inputs to the carbon models in a low-cost way and biomass will be one extremely important input into those carbon models. The other dimension would be whether we can get better at detecting land management practices *via* remote sensing. There are improvements in understanding land cover, land use, and land use change. However, land management, particularly with the subtleties of intensive grazing, crop rotations residue, etc., is hugely important for non-CO_2 fluxes, and any improvement would be of great interest to the whole GRA community. Improving approaches, methodologies, technologies, etc., benefits everybody and it is an area where no one can really do it alone. There are always benefits from greater datasets and diversity of data, systems, and conditions to validate the models.

Jørgen E. Olesen (FACCE-JPI Scientific Advisory Board - SAB) presented the FACCE-JPI's revised Strategic Research Agenda (SRA) and noted that they are trying to integrate agricultural GHG emissions with other landscapes, such as forestry and other land uses. The SRA will address the effects on the range of GHGs. How can this be accounted for? It is noteworthy to address what we measure and how we measure it, and the way we address this with our actors and stakeholders is extremely important in terms of how they act on this. There is an issue in terms of aligning our estimates on emissions, and that does not just go with the carbon emissions, but also with nitrous oxide and methane emissions. Therefore, when it comes to agricultural emissions, it is really complicated because we have an extreme diversity in terms of emission sources and in terms of potential technologies to deal with this. There is a need for some sort of mechanism that also applies to a greater European perspective (even a global perspective) on getting an alignment or documentation on technologies in terms of the validity of technologies that you apply to farmers and other actors, on how to apply technologies to reduce the emissions. The mechanism could be specific, maybe feed amendments to cattle or what you do to your fertilizers, etc., but it would certainly imply that you have some way of dealing with your emissions. Documentation is needed and we need to align our national inventories and how we the incorporation of this information within farm scale or food base calculations and GHG emission effects. The challenge is in terms of addressing the state of technologies to improve our enhancements on the GHG reductions and this requires documentation.

The challenge of incorporating mitigation and inventories was also discussed. This area is of huge importance and extremely challenging, as default inventories are not particularly well designed for this. Trying to incorporate a particular change in management or new technology that is explicit and direct is very difficult, and activity data is needed to go along with that. There is no guidance on how to segregate your sources, etc. There needs to be more guidance on the "burden of proof" required to incorporate emerging communication technology in the inventory. Regarding the use of inhibitors applied to animal feed or soil to reduce methane or nitrous oxide, "who is saying what's the minimum required before this is acceptable"? That would be an area of importance and interest, also in the GRA community, to try to help provide a little bit more guidance on how to implement explicit mitigation practices. It may require looking across countries that have been successful incorporating explicit mitigation practices into their inventory. An example is the fertilizer world, in which there is industry-based practice (the four 'R's) right source, right rate, right time, and right place, and the industry promotes this throughout the farming and fertilizer communities, etc. The question is how many GHG inventories can actually capture rate, place, source and time? This demonstrates the length we need to go before the inventory is useful for mitigation, tracking progress and indices.

Gary Lanigan (Teagasc) noted that when they changed their nitrous oxide inventories, they provided more emission factors than the inventory could take. They have emission factors for ammonium nitrate, urea, urea plus MBPT, and nitrification inhibitors by soil type. The inventory cannot take the soil data; therefore, the activity data is lagging. In terms of the science, there may be as many mitigation options and as many emission factors possible, however, the activity data cannot keep up. The result is an inventory that is not flexible. This is not a reflection on the inventory, but the wider issues around the collection of data. Regarding soil carbon, farmers (dairy and beef), companies and advisors ask how to reduce emissions, and will the emissions be counted? Forests of flux towers have been placed in various areas in order to get annual carbon budgets and to try to get algorithms between the sites where there was variance and measuring below ground biomass, which is the key unknown for all biochemical models, to try to get them to interact with remote sensing data. Remote sensing is used to ascertain when farmers fertilize a field as an example, and it would replace surveys and provide more accuracy for the inventories.

The participants also commented on the current way the inventories are working and how they do not reflect reality in terms of CO_2. Jørgen Olesen is leading the European project on GHG emissions from crop residues and mentioned the upcoming stakeholder webinar (22nd April 2021). The GHGs from crop residues are not reflecting reality. The fundamental challenge is the way we currently account for GHG emissions in our national inventories and they are typically downscaled. The same methodology is applied at the farm scale, food scale, etc., which is based on the IPCC methodology. This is a relatively simplified emission vector-based methodology that doesn't necessarily reflect reality. We should implement methodology that accounts for all applied scales and that better reflect the reality that we are dealing with.

María José Sanz Sánchez (Basque Centre for Climate Change) reflected on the discussions and noted that it was a rare event to have the systematic observation and modeling communities (including the IAMs) at the same forum discussing the same problem and finding a solution. Going forward, it is important to continue these exercises to reconcile the different perspectives and effects, which will result in estimations. It is important that we, the communities that are here today, collectively identify where we can join our efforts and improve on estimates, but also to better understand the fluxes and how those fluxes are related to the stocks. That includes better data collection on the inventory side or other activities to improve the models. There is one critical point, and it is the interoperability across the scales, which requires that we start thinking altogether regarding the global guides, the inventory guides and even the technical people and scientists who are working more on a systems approach like farm level, etc. This does not mean that we need to organize them completely or do the same approach for every scale, but there are ways to think about the interoperability and the technology, and the digital data methodologies today are tools that are useful for that.

Something that the inventories will not be able to stop is the use of remote sensing data to produce data that is supposed to be compatible with the data inventories. The inventories may move towards using this data, but also the reactivity data. For example, with forest, it appears to be an easy task to use remote sensing data. However, it is not as easy as we thought, and that is probably good to share with some other communities, like the systematic observation community that is using this data. It is important that we keep in mind while identifying where we can work together and progress, that there are still problems on linking the estimations of GHG and how they change with tracking the impact of policy. This is still an area where there is a huge gap. Therefore, thinking together about global policies which are consistent, and which are making a difference, also at the local, national and European level, is an important point that we should not forget. There is a need to work towards understanding collectively why these policies have changed trends. We should not be obsessed necessarily about too much accuracy; it is important for some of the communities to realise that accuracy may not be as important as understanding the trends. We should focus more on the trends and not so much on reducing uncertainty to 5%. We should also start engaging with other component communities and not deny that the industry, private sector, and the land use sector are going very fast. They are introducing new technologies that the inventories are not able to grasp yet. We may need to think also about how the private sector is looking at these activities and even join forces for some aspects. The corporations are now engaging in a very thorough and continuous effort of increasing cooperative reporting and making that information publicly available, which is another source to compare with and will add more noise into the system. Therefore, if we do not think about that early enough, we may have some problems later. We need to identify topics where we can start working together and producing this constructive atmosphere across the communities. Incorporating other tools, such as how to better estimate lateral transfers and understand where there is imbalance, is something that we could do. It will help to focus where we can improve, and even inventory modeling is also something we could consider.

Frank Dentener (Joint Research Centre) mentioned that, regarding the inventory work, it may move to inventory methods modelling. What will be needed is an activity or platform where models that are to be used must be benchmarked. JPI Climate and FACCE-JPI can start working together on setting up this activity. There is a lot of work in preparation to help this process.

Alistair Manning (Met Office) stated that the UK has submitted a verification using inverse modeling to every gas other than CO_2. In terms of quantifying information, the UK government has asked repeatedly to try to break down the total methane emission estimates for the UK into the different sectors, and thereby also the subsectors within. Therefore, the focus of the work is on methane and nitrous oxide, trying to break down into the subsectors and provide direct feedback to the UK government as to where their inventory may need some more development. It is important to have a good network of atmospheric measurements, not just satellites but tower-based systems. These are crucial within a country because countries are quite small, and a country like the UK is very cloudy, so satellite data is very sparse in the UK. Therefore, having ground-based data is also important.

The other thing about measurements, in terms of trying to break down those sectors is the use of isotopes and the use of atmospheric potential oxygen to measure them out of oxygen in the atmosphere, and then give infrared GHG emissions in terms of fossil fuel. Therefore, splitting down the problem into the different sectors is crucial and is what is regularly asked for by the policymakers. Atmospheric measurements are potentially useful for gases like CFCs. The timeliness of giving data back to the UK government in terms of emissions is at least a year ahead of what the inventories can do because they must wait for the data to be collected. Therefore, it is a timeliness benefit. The key thing that we do in the UK is to work very collectively with the inventory makers. We engage with them very regularly and try to maximize the use of inverse modeling data within their estimates to try to improve the inventory.

Frank McGovern (Chair, JPI Climate) mentioned that there would be a document based on the workshop findings. Through the discussion, the need for follow up meetings was identified. FACCE-JPI will have their SAB meeting soon and the Governing Board of JPI Climate will be meeting in June 2021. There is a need to open that dialogue process and as previously indicated, there is a need to engage with the policy community, including at the European level. It is possible to include communities outside of Europe as well. It is hoped that we could arrange some sort of follow up activity in Q2 2021. We anticipate an engagement or science policy meeting with policy makers. We need to identify areas that we need to expedite and potentially have a call on priority areas. It is something that can be followed up with a two-hour advisory body meeting, with an additional meeting later in Q3 2021, to identify areas of priority of inventory investment.

FACCE-JPI noted that it would be relevant to also involve its Stakeholder Advisory Board. This Board is relevant to get stakeholders to participate in finding solutions, particularly on the agricultural side, with those on the policy side for the climate issues. Additionally, the views from those that are on the ground trying to grasp with how to deal with this from not only the industry perspective, but also the policy perspective, will be very useful in this process.

Heather McKhann (French National Institute for Agriculture, Food and the Environment - INRAE; FACCE-JPI Coordinator) considered that this workshop is a very good first step. The next steps are to bring together some experts, some of our funders and policy makers and different stakeholders. The challenge is to find that intersection. As pointed out by several people, FACCE-JPI is very focused on agriculture, and it has many agricultural ministries around the table. It is not only agricultural ministries but specific people, and sometimes they do not necessarily have the whole range of topics there in their portfolio. Therefore, a meeting and working together to come to some kind of common understanding and common priorities would be the next steps. Flexibility is required and it might be that the two JPIs' needs are slightly different. Therefore, we could imagine something modular, for example, which would cover different aspects of what was discussed at the workshop (which covered a very large area). There were good inputs and there is a lot of urgent things to be done and we need to see how to go forward. We have a meeting of our SAB next week. This item is not specifically on the agenda. However, we can find some time to discuss it. The Governing Board meeting is in June and it would be imperative to have a follow up meeting on a small or large scale in the next three or four months.

Amrit Nanda (Vice Chair, FACCE-JPI Stakeholder Advisory Board - StAB) recognised that there is some overlapping of interests. However, FACCE-JPI represents more agriculture and JPI Climate is more focused on climate. Finding that connection of how a joint action on this topic can benefit both JPIs and be of interest to all the funders is a challenge. However, it is also very interesting because this is the kind of cross-cutting research that is needed. From the StAB side, we are interested in being involved in this and providing information on how our industry perspective can be applied and how that could be of interest, so the StAB is looking forward to the next steps.

Claude Nahon (JPI Climate Transdisciplinary Advisory Board - TAB) highlighted the societal behavior aspect in these discussions. We may need to bring somebody on board who is an expert in the behavior of customers because there is an opportunity in that area to align with the agricultural transformation.

This is an extremely relevant and complex issue because this has to do with people in all parts of society and all parts of the food supply chain. This is an area where we need to bring together the natural, social and humanities scientists. We need to highlight how we as societies change and how societies are about people. It is something that FACCE-JPI has tried to bring to the forefront as part of the recent SRA.

2. Conclusions and Next Steps

The JPI Climate Chair closed the meeting by thanking everyone who attended online and contributed to the discussion.

The issues raised are related to the evolving inventory systems and the regionalised and local tools implemented to inform climate plan strategies and the lack of coherence in the reporting.

The discussion identified many issues and solutions in which to progress forward. The key points from the discussion include:

- It was proposed to organise follow up meetings between JPI Climate and FACCE-JPI (Q3/4 2021) and to include the workshop delegates, as well as others, to keep the dialogue process open.
- More engagement is needed with the policy community on a national and international level. A science policy meeting would provide an opportunity to convey the issues and provide the solutions.
- Aim for a joint meeting between JPI Climate and FACCE-JPI to identify areas of research priorities and investment, including around model comparison and collection and measuring of inventory related data. Involve Scientific Advisory Boards and Stakeholder Advisory Boards from both JPIs.
- A joint call to be planned for 2022 with the objective to provide more accurate and consistent data sets over time and space & harmonisation of these with model analysis, as well as to enable intercomparison of models and improve the use of available data sets.
- A mechanism on a global perspective was proposed to get alignment or documentation on the various technologies in terms of the validity of the technologies that apply to farmers, etc., and how to apply technologies to reduce the emissions.
- More guidance on the "burden of proof" is required to incorporate emerging communication technology in the inventory.

- Methodology needs to be implemented that accounts for all applied scales and that better reflect the reality that we are dealing with.
- There is a need to think about how our approaches can be more interoperable. It is important to keep in mind, while identifying where we can work together and progress, that there are still problems on linking the estimations of GHG and how they change with tracking the impact of policy.
- In terms of measuring, it is important to have a good network of atmospheric measurements, not just satellites but tower-based systems.
- It is relevant to have interaction between stakeholders in agriculture and those on the policy side for climate issues.
- There is a need to identify topics which enable communities to start working together and produce a constructive atmosphere across communities.
- The incorporation of tools i.e., how to better estimate lateral transfers and understand where there is imbalance, is also a priority.

The next steps

Step 1:	Follow up meetings between JPI Climate and FACCE (Q3 2021); FACCE SAB meeting (April 2021); JPI Climate GB meeting (June 2021)
Step 2:	Aim for an open dialogue process with Policy makers (national and international) and arrange a scientific meeting in Q3/4 2021;
Step 3:	Outline of a Joint meeting Q3/4 2021 to identify areas of research priorities and investment, including around model comparison and collection and measuring of inventory related data;
Step 4:	Reach out and engage with other communities, such as industry, private and land use sectors (Q3/4 2021);
Step 5:	A Joint Call 2022 with the objective to provide more accurate and consistent data sets over time and space & harmonisation of these with model analysis as well as to enable intercomparison of models and improve the use of available data sets. The organisational details of the call should also be discussed and agreed between both JPIs.

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