R2D2: Quantifying Regrowth and Recovery from Deforestation and Degradation at Large Scale
4 – 6 March 2024

Overview

Protection of old-growth forests is the priority for reducing land-use sector emissions and maintaining the forest carbon sink. Overall, there are large differences in estimates relating to the forest sink. **Accurately quantifying the forest carbon sink is key** to closing the gap between different estimates. In the regions that have experienced deforestation and degradation, quantifying the post-disturbance and regrowth-related carbon fluxes is critical to gain a complete and accurate understanding of the forest carbon budget at all scales and for different nature-based solutions and climate-smart land use efforts.

Research is increasingly focusing on improving our large-scale understanding of the carbon fluxes following forest clearing and disturbances. Post-disturbance forest dynamics are complex resulting in both ongoing carbon losses, e.g., due to post-disturbance mortality or various land use trajectories, and carbon gains due to forest recovery on abandoned deforested or degraded forest landscapes. Quantifying these spatially and temporally variable dynamics benefits from applying many approaches.

Across all scales of the research community (field-based to remote sensing-based) and across all sectors (academic to policy), there is a growing **desire and requirement to improve how the regrowth and recovery from deforestation and degradation (R2D2)** are quantified and reduce their uncertainty.

With the availability of remote sensing data, the research in this field is evolving even more rapidly. Thus, there is a **need to take stock of the current and emerging approaches that monitor forest regrowth and recovery** from deforestation and degradation with a global forest focus. Taking stock of available approaches would better connect and coordinate the various ongoing research efforts to provide more community-consensus input to key science and policy questions about the magnitude, distribution, and trends in forest carbon sinks and sources and how they relate to various efforts improving the GHG accounting performance and enhancing the sustainability of the land use sector.

Specific aims and outcomes of the R&D workshop:

- **Taking stock:** Focusing on R2D2 forests, to synthesize our understanding of the current approaches to calculating their carbon emissions and removals at all scales, with a focus on how information can be scaled over large areas.
- **Collaboration:** identify cross-overs in groups' approaches, areas with scope for collaboration, and gaps for future research.
- **A review paper** on the current technical approaches available to monitor and estimate carbon fluxes of forest R2D2 dynamics. This paper will assess the advantages and disadvantages of the approaches with input from all authors, current gaps in the research, and applications of approaches for GFOI and other communities.

Location

The workshop was held in-person at the GFZ, Potsdam, Germany. Online participation was also possible.

Organisers

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Keywords and abbreviations

R2D2 (Regrowth and Recovery from Deforestation and Degradation); C (carbon); RS (remote sensing); EO (earth observation); EUDR (European Union Deforestation Free Regulation); NFI (National Forest Inventory)

Summary of the workshop

Day 1

Scientific and policy requirements from research on R2D2, gaps and priorities (Session 1): An overview of key policies driving research and reporting on secondary and degraded forests (R2D2) highlighted major EU targets, including the EUDR, and countries approach of the managed land proxy. How countries define degradation varies, and separating emissions and removals in Forest land Remaining Forest land remains a challenge. Brazil is a crucial example of a country with key deforestation and recovery targets in place at national and regional scale. There remain uncertainties on estimating the sink related to secondary and degraded forest. Identifying degraded forests is particularly difficult, and their other ecosystem services (e.g., temperature regulation, rainfall) should be considered to quantify their full benefits.

Recent advances for mapping R2D2 forests and quantifying their C fluxes (Session 2 and 3): Recent advances in mapping secondary and degraded forests (R2D2) include improvements in remote sensing data, especially in moist tropical forests. High-resolution data now incorporate causes of degradation (e.g., logging, fire), requiring local training data and expertise. Maps of R2D2 forests can improve global forest and demographic models, helping to reconcile differences between datasets. There has also been RS advancements in looking at carbon fluxes within R2D2 forests. Still a very common approach is to integrate maps identifying their spatial and temporal extent with separate (spatial) data on their carbon fluxes (gain-loss approach). Advances in carbon flux mapping use gain-loss approaches and integrate field data or remote sensing to estimate regrowth rates. Emerging methods track stock changes over time, with LiDAR and CO_2 enrichment experiments offering insights into forest vulnerability. Recent data have shown that young and old-growth forests are decreasing globally, whilst mature forests are increasing, with consequences for the carbon sink.

The Biophysical and social drivers of forest regrowth (Session 3): New advances have been made in identifying the global areas where it is biophysically feasible for natural regenerating forests. However, the socio-economic variables are harder to model. There is a growing field of research showing the benefit of indigenous collective property rights and local governance in reducing

deforestation and promoting regrowth, highlighting the need to prioritise local stakeholder-driven project and the need for improved local governance.

Key points from breakout group discussions:

Definitions: Is it possible to have a clear definition of forest degradation due to different national and scientific interpretations? E.g. Remote sensors have evolving definitions of R2D2. Based on what the sensors can measure. Which may increase with space and time. Forest ecologists on the other hand may have a more consistent definition. Forests are more than just carbon and provide other functions and therefore also impact the definition of R2D2 forests.

Policies: There are numerous global to local level evolving policies, which are all action oriented and need for timely and high-resolution data. It is crucial not to forget indigenous groups and local experts who may not write down their policies and knowledge.

Measuring/monitoring R2D2 forests: EO can be used as compliance tools and needs to be connected with in-situ measurements. There is a need for open and transparent data (and their associated uncertainties) to serve multiple stakeholder and purposes. Its crucial to consider the practical consideration and technical readiness of measurement approaches without halting rapid action in policy progress that is needed.

Day 2

Recent Advances in measuring degradation and associated emissions (Session 6): Despite fast pacing advances of detecting disturbances with RS data (from Landsat to using Radar) there is still a need for good, high-level reference data and visual interpretation and understanding. By looking at different sensors, we can look at the type and intensity of disturbance occurring; the driver matters for both impacting the degradation/deforestation impact and the potential of regrowth/recovery. E.g. the impact of the edge effect and fires is crucial for measuring C emissions, which may persist after the degradation event. Measuring C emissions from disturbances can begin to applied in a stock-change approach using LiDAR data such as GEDI. Crucial to investigate the temporal changes of degradation, which remain overlooked in policies, and continue to be a source of C at high rates. At the local scale, management interventions may be needed, e.g. as climate change and degradation favours invasive liana species and thus limit recovery.

Recent advances in measuring regrowth and recovery and associated removals (Session 7): regrowth is spatially and temporally complex and is influenced by its driver. Research at regional scales has shown the impact of charcoal production on carbon removal and at pan-tropical scale the impact of fires, logging and climate on rates of regrowth. Contrast to the tropics, where RS data is commonly used in reporting, in Europe there is a large array of NFI cycles that provide valuable input with potential to be integrated with EO data, though this is generally lacking. Furthermore, there is a need to include more information in NFIs that is applicable to R2D2 forests e.g. forest age classes. Field data and remote sensing approaches can provide complementary approaches to measuring forest regrowth (e.g. as new research is showing in the Atlantic forest), where field data can also be used to benchmark and bias correct forest age maps and estimates of carbon accumulation.

Future of measuring R2D2 (Session 8): Need to move towards operational systems and ones that predict risks to terrestrial carbon sinks and their response management and these need to be informed

by data emerging, especially remote sensing. There is an ongoing need to measure uncertainty and reduce it in future estimates. We need process-based models to understand the potential risks to C sinks and make better decisions in light of these risks. Process-based models can act as integrators of data on different scales (RS and ground). Can use future, long-term monitoring of forests e.g. GEDI to attribute biomass differences to forest policies on avoided deforestation/degradation or enhanced regrowth/recovery. In a world where climate policies often prioritise tree structures other than natural regrowth e.g. agroforestry, plantations etc, it becomes ever crucial to distinguish these for accurate R2D2 mapping and quantifying their changes in carbon, diversity, structure etc.

Key points from breakout group discussions:

Mapping activity data: Many disturbances blend, therefore need monitoring at different scales and integration of different datasets. Can we move away from anthropogenic and natural to an intentional and unintentional approach? Need for a combination of sensors to understand drivers of degradation. That is the direct drivers, rather than the underlying agents of degradation. Future work can also consider what happens to the land in the period after deforestation/degradation and before regrowth. Compared to even a decade ago, we are moving steadily in an era of transparency.

Measuring carbon fluxes from R2D2: Need for repeat measurement to look at structural and carbon changes after disturbance, this will help to look at degradation and regrowth as a process rather than separate events. There is sufficient data to validate space for time substitution approach as well as compare the current carbon emission and removal factors that exist and determine if they align.

Beyond carbon: There are many other variables that we can measure that give us indicators of how forests behave as dynamics processes. E.g. water and temperature – what does disturbance mean for these biophysical parameters. The forest policy realm is driven by the markets connection to carbon credits: we know the value of carbon in dollars, there is no such monetary value for other very measurable parameters e.g. leaf area index. However, it is also important to consider that data does not exists in a vacuum and data ownership and fair data usage needs to be considered.

Day 3

Beyond Carbon (Session 10): It is crucial to value a tree for more than just its carbon and put biodiversity at the core, building a network of reference dataset using multi-dimensionality to increase confidence in restoration success and compare this to counterfactuals. Furthermore, it is crucial to incorporate local and indigenous people at project and regional to global scale. Need to consider the potential barriers of carbon quantification methods at local scale, which may be overlooked and how they may limit implementation in practice. It is possible to now detect degradation at 3m using Planet data, and work and integrate this with local people on how to use the data in a practical and logistical way, using a suitable reference system. In reality, carbon is an important but secondary co-benefit. When it comes to measuring biodiversity at project level, payments will not be based on measurable outcomes but rather activity. There is a need for an upfront payment system to make it work.

Detailed Agenda

Monday 4th March 2024

* Denotes Online participant

Time	Session	Speaker
8.30 - 9.00am	**Registration, morning Coffee, Meet and Greet**	
9.00 – 9.40am	**Welcome and Introductions**	**Viola Heinrich and Martin Herold**
9.45 – 11am	**Session 1: The Big Picture**	**Chairs: Viola Heinrich and Martin Herold** 9.45 – 10.00: Giacomo Grassi* - Overview of the EU and IPCC contexts related to land use CO2 fluxes 10.00 – 10.15: Gert-Jan Nabuurs - Challenges in land use chapter in IPCC 6AR 10.15 – 10.30: Daniela Requena Suarez - Challenges in R2D2 in country-level reporting 10.30 – 10.45: Luiz Aragão* - Country perspective: Brazil 10.45 – 11.00: Open Discussion and Q&A
11.00 – 11.30am	**Coffee Break**	
11.30 – 12.30	**Session 2: Current large-scale approaches of forest area/flux change analysis**	**Chairs: Flavia de Souza Mendes & Dominick Spracklen** 11.30 – 11.40: Clement Bourgoin* – JRC: Long-term (1990-2023) monitoring of forest degradation, deforestation and recovery in the humid tropics 11.40 – 11.50: Stephen Sitch – GCP: Improving process-based models) and RECCAP (regional carbon cycle assessment and processes) 11.50 – 12.00: David Gibbs – WRI: Large-area forest carbon flux mapping using a geospatial data integration framework 12.00 – 12.10: Philippe Ciais – Ctrees: C budget of secondary forests from growth rates and biomass maps 12.10 – 12.30: Open Discussion and Q&A
12.30 – 13.30	**Lunch and optional walk around Telegrafenberg**	
13.30 – 14.45	**Session 3: Scientific Introductions to R2D2**	**Chairs: Toby Jackson & David Gibbs** 13.30 – 13.40: David Lapola* – Amazon forest degradation: an overview 13.40 – 13.50: Robin Chazdon – Assessing the global potential for forest regeneration across the tropics and subtropics 13.50 – 14.00: Simon Besnard – Global covariation of forest age distribution shifts with the net carbon balance 14.00 – 14.10: Susan Cook-Patton* – Protect young secondary forests for more rapid carbon removal

Time	Session	Speaker
		14.10 – 14.20: Ricardo Dalagnol* – Attributing forest disturbance to its agents, can we scale the small-scale to the large-scale?
		14.20 – 14.30: Kathryn Baragwanath* & Nilesh Shinde* – The effects of governance on secondary forest growth
		14.30 – 14.45: Open Discussion and Q&A
14.45 – 15.15	**Coffee Break**	
15.15 – 16.30	**Session 4 - Breakout groups on 'Needs for improved R2D2 data and approaches'**	Groups and Facilitators: Group 1: Evolving international policy and data needs. Led by Martin Herold, Katja Berger, Jo House & Tim Stassin** Group 2: Research Gaps: R2D2 science questions. Led bySimon Besnard, David Gibbs, Jess Baker* and Alex Runge Group 3: Country-level gaps and perspectives. Led by Daniela Requena Suarez, Viola Heinrich, Luiz Aragão and Linda Luck** ** These 2 sessions were merged on the day
16.30 – 17.30	**Session 5 – Feedback from breakout groups**	**E.g. One person per group**
17.30	**** R2D2 ** Group Picture**	**Before Zoom people log off – we can take a screenshot of all** 😊
18.30 onwards	**Open invitation to join a dinner at L'Osteria (Potsdam)**	

Tuesday 5th March 2024

Time	Session	Speaker
9.00 – 9.10am	**Summary from Day 1**	**Martin Herold**
9.10 – 10.30am	**Session 6: Recent advances: Degradation (1/2)**	**Chairs: Flavia de Souza Mendes & Toby Jackson** 9.10 – 9.20: Loïc Dutrieux* - Europe's forest disturbances and the challenge of their attribution 9.20 – 9.30: Alba Viana Soto - Detection of multiple forest disturbances in Europe using the Landsat Archive (1985-2023) 9.30 – 9.40: Johannes Reiche - Forest disturbance mapping and characterization using radar satellite data 9.40 – 9.50: Amelia Holcomb – Measuring small-scale forest disturbance with spaceborne lidar 9.50 – 10.00: Celso Silva-Junior* – Carbon Emissions at Forest Edges: Current Perspectives and Future Challenges 10.00 – 10.10: Andy Marshall* – Forest Restoration and Climate Experiment (FoRCE) 10.10 – 10.30 Open Discussion and Q&A

10.30 – 11.00am	Coffee Break	
11.00 – 12.30	Session 7: Current large-scale approaches of forest area/flux change analysis	**Chairs: Alba Viana Soto & Tom Pugh** 11.00 – 11.10: Camila Silva* – Forest Fire emissions in the Brazilian Amazon 11.10 – 11.20: Mengyu (Amber) Liang – Combining GEDI and Landsat data for understanding forest dynamics associated with restoration interventions in East Africa 11.20 – 11.30: Niamh Kelly – A short overview of European forest regrowth data and gaps 11.30 – 11.40: Laura Vedovato* and Pedro Brancalion* – "Recovery and regrowth across restoration typologies in Atlantic forests 11.40 – 11.50: Yidi Xu – Changes in biomass in boreal and tropical zones over multiple time periods 11.50 – 12.00: Toby Jackson – Assessing a 500 ha logged forest restoration experiment in Borneo using repeated airborne LiDAR 12.00 – 12.10: Na Chen* – Revealing the Spatial Variation in Biomass Uptake Rates of Brazil's Secondary Forests 12.10– 12.30: Open Discussion and Q&A
12.30 – 13.30	Lunch and optional walk around Telegrafenberg	
13.30 – 15.00	Session 8: R2D2 into the future	**Chairs: Simon Besnard and Luisa Teixeira** 13.30 – 13.40: Robert Kennedy – Whither R2D2? Perspectives in tropical and temperate forests through the lens of C3PO 13.40 – 13.50: Rosie Fisher – The diversity of approaches to forest demography model in in the next generation of Earth System Models. 13.50 – 14.00: Nathalia Nascimiento* – Forest Disturbance Drivers in the Atlantic Forest: Implications for Carbon Storage 14.00 – 14.10: Tom Pugh – Forcing a DGVM with observations of forest structure and dynamics 14.10 – 14.20: Laura Duncanson* – Toward GEDI-based forest change monitoring in protected areas 14.20 – 14.50: Open Discussion and Q&A 14.50 – 15.00: Viola Heinrich – Introduce next breakout groups
14.00 – 15.30	Coffee Break	
15.30 – 17.30	Session 9 - Breakout groups on summarising and comparing approaches	Facilitators: Group 1: Activity data – i.e. area monitoring of degradation and regrowth. Led by Martin Herold, Simon Besnard & Tim Stassin Group 2: Emission and removal factors – Summary and comparing evolving approaches for monitoring degradation/disturbance and regrowth and recovery. Led by: Viola Heinrich, Amelia Holcomb & Linda Luck

		Group 3: Beyond Carbon in R2D2. Led by Daniela Requena Suarez, Dominick Spracklen & Alex Runge
		*Zoom links to join these sessions are available at the end of this agenda.
18.30		**Dinner for all in-person participants at the Genusswerkstatt (Potsdam)**

Wednesday 6th March 2024

Time	Session	Speaker
9.30 – 10.30am	**Session 10: Beyond quantifying carbon**	**Chairs: Luisa Teixeira & Katja Berger** 9.30 – 9.40: Ruben Valbuena – Monitoring, Reporting and Verification of Biodiversity and Ecosystem Services 9.40 – 9.50: Flavia de Souza Mendes - Developing and bringing to society new solutions in forest monitoring and sustainable land use 9.50 – 10.00: Ben Newport – Messy material realities of quantifying carbon 10.00 – 10.10: [Anny N'Guessan* – Restoration of ecosystem services in secondary forests and agroforestry systems.] – Unable to present 10.10 – 10.30: Open Discussion and Q&A
10.30 – 11.00am	**Coffee Break**	
11.00 – 12.30	**Session 11: Feedback from breakout groups from the previous days**	**Chairs: Viola Heinrich, Martin Herold & Daniela Requena Suarez** 11.05 – 11.25: Feedback from Group 1 11.25 – 11.45: Feedback from Group 2 11.45 – 12.05: Feedback from Group 3 12.05 – 12.30: Open Discussion and Q&A
12.30 – 13.30	**Lunch and optional walk around Telegrafenberg**	
13.30 – 15.30	**Session 12: Paper preparation and closing**	13.30 – 14.20: Viola Heinrich: Paper overview, discussion 15.00 – 15.30: Closing remarks: Viola Heinrich & Martin Herold
15.30 onwards	**Workshop finishes**	**Departure of in-person participants**

Participant List

First Name	Last Name	Institute	In-person (P) or online (O)
Viola	Heinrich	GFZ	In-person
Simon	Besnard	GFZ	In-person
Celso	Siva Junior	IPAM	Online
Amelia	Holcomb	University of Cambridge	In-person
Flavia	Mendes	Planet Lab	In-person
Rosie	Fisher	CICERO	In-person
Mengyu	Liang	UMD	In-person
Ricardo	Dalagnol	JPL	Online
Henrique	Cassol	Bluebell Index	Online
Martin	Herold	GFZ	In-person
Tom	Pugh	Lund University	In-person
Andy	Marshall	University of Sunshine Coast	Online
Yidi	Xu	LSCE	In-person
Philippe	Ciais	LSCE	In-person
Susan	Cook-Patton	Nature Conservancy	Online
Kathryn	Baragwanath	Harvard University	Online
Clement	BOURGOIN	JRC	Online
Laura	Vedovato	Instituto de Pesquisas Tecnologicas (IPT)	Online
Camila	Silva	IPAM	Online
Laura	Duncanson	UMD	Online
Thais	Michele	University of Exeter	Online
Robin	Chazdon	University of the Sunshine Coast	In-person
Jo	House	University of Bristol	In-person
Ruben	Valbuena	SLU	In-person
Stephen	Sitch	University of Exeter	In-person
Daniela	Requena	GFZ	In-person
Na	Chen	MIT	Online
Luiz	Aragão	INPE	Online
Alba Viana	Soto	TUM	In-person
Nathália	Nacimento	University of São Paulo	Online
Ben	Newport	University of Bristol	In-person
Anny	N'GUESSAN	Université Félix Houphouët-Boigny	Online
Justin	Kassi	Université Félix Houphouët-Boigny	Online
David	Lapola	University of Campinas	Online
Lilian	Blanc	CIRAD	Online
Tommaso	Jucker	University of Bristol	Online
Toby	Jackson	University of Bristol	In-person
Loïc	DUTRIEUX	JRC	Online
Guido	Ceccherini	JRC	Online
Giacomo	Grassi	JRC	Online

Joana	Melo	JRC	Online
Nilesh	Shine	University of Massachusetts Amherst	Online
Amani	Bienvenu Konan	Université Félix Houphouët-Boigny	Online
Evan	Fricke	MIT	Online
Cesar	Terrer	MIT	Online
Julie	Betbeder	CIRAD	Online
Charlotte	Wheeler	University of Cambridge	In-person
Jens	Vanderzee	WUR	In-person
Callum	Smith	University of Leeds	In-person
Annemarie	Eckes-Shephard		Online
Bruno	Herault	CIRAD	Online
Gert-Jan	Nabuurs	WUR	In-person
Iain	McNicol	University of Edinburgh	In-person
Johannes	Reiche	WUR	In-person
Nancy	Harris	WRI	Online
David	Gibbs	WRI	In-person
Joanne	White	Canadian Forest Service	Online
Robert	Masolele	WUR	In-person
Anne-Juul	Welsink	WUR	In-person
Sietse	van der Woude	WUR	In-person
Bart	Slagter	WUR	In-person
Johannes	Balling	WUR	In-person
Katja	Berger	GFZ	In-person
Lina	Mercado	University of Exeter	In-person
Dominik	Spracklin	University of Leeds	In-person
Una	Kelly	University of Münster	In-person
Jess	Baker	University of Leeds	Online
Niamh	Kelly	WUR	In-person
Arnan	Araza	WUR	In-person
Xueyuan	Gao	UMD	Online
Aline	Pontes-Lopes	INPE	Online
Luisa	Teixeira	Planet Lab	In-person
Olga	Nepomshina	GFZ	In-person
Alexandra	Runge	GFZ	In-person
Timothée	Stassin	GFZ	In-person
Camilo	Zamora	GFZ	In-person
Linda	Luck	GFZ	In-person
Robert	Kennedy	Oregon State University	In-person
Sascha	Delecluse	UCLouvain	Online
Sugandha	Sugandha	University of Münster	Online
Sarah	Bereswill	PIK	In-person
Rene	Colditz	JRC	Online

Yanlei	Feng	Berkeley	Online
Marie-Therese	Schmehl	Universität Potsdam	Online
Zhilin	Tian	GFZ	In-person

Group photo

Funding