GEO-TREES

Full Title: Forest Biomass Reference System from Tree-by-Tree Inventory Data

Short Title: GEO-TREES

Category: Community Activity

1. Executive Summary

GEO-TREES shall support the establishment and development of a global activity of *in situ* biomass reference measurement sites, the *Forest Biomass Reference System (FBRS)*, to complement existing and planned space-based forest biomass observation instruments. These sites will provide integrated, multi-observational, multi-scale reference data to support global space-based forest biomass mapping and will include high-quality georeferenced data on tree biodiversity. Climate change concerns impose an immediate and urgent demand for verifiable and consistent measures of forest biomass in order to reduce the major uncertainties in calculations of carbon stocks and fluxes associated with the terrestrial biosphere. International agreements have made it imperative to obtain accurate estimates of biomass and its changes: under the Paris Agreement (Article 4, paragraph 2) each nation needs to prepare, communicate and maintain successive Nationally Determined Contributions (NDCs) that it intends to achieve.

The key activities during the 2021-2022 GEO work programme are to:

1. Set up the GEO-TREES activity, in particular establish the structure of the project and the governance model.
2. Identify and reach out to potential partners to support a GEO-TREES coordination office.
3. Consolidate an implementation plan and funding roadmap for the *Forest Biomass Reference System*.
4. Link the activity with the GEO GFOI (regarding forest biomass activities) and GEO-BON (regarding forest biodiversity activities) Flagships.
5. Identify and reach out to potential funding partners and seek systematic funding for the *Forest Biomass Reference System*.

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2. Purpose

2.1 Rationale

There is an urgent demand for verifiable and consistent measures of forest biomass in order to reduce the major uncertainties associated with carbon stocks and fluxes of the terrestrial biosphere. Climate change concerns and resulting international agreements have made it imperative to obtain accurate estimates of biomass and its changes. For example, under the Paris Agreement (Article 4, paragraph 2) each nation needs to prepare, communicate and maintain successive Nationally Determined Contributions (NDCs) that it intends to achieve.

Space Agencies responded to this need by developing dedicated space-based observation systems. However, to optimally utilize these space assets global, reliable, permanent high-quality forest biomass reference measurements on the ground are needed and should form

an integral part of the world's system of space-based Earth Observation missions aimed at measuring forest biomass globally. These ground reference measurements are essential for accurate calibration and validation of the space measurements and for their wide acceptance by the user community, which range across many areas, including climate modelling, national reporting to the UNFCCC, and land-use management.

Where satellite products are to be used in reporting, the ground data used for algorithm training and validation should meet the recommendations of the dedicated CEOS Land Product Validation (LPV) biomass protocol. This protocol targets standardized reference data collection optimized for use in Earth Observation applications. Since the next generation of Earth Observation sensors will be characterised by a wide diversity of sensing techniques and ever-increasing spatial, spectral and/or temporal resolution, for reference data to be fit for purpose they must also be suitably flexible and high-resolution.

To address the need to systematically collect and share these high quality in-situ data, we propose the creation of the FBRS. This system will be composed of 100 core sites and 210 complementary sites distributed globally for which *in situ* tree-by-tree data shall be collected and shared openly. In addition, the FBRS will provide consistent, standardised estimates of plot level AGB for these sites. Since close to three quarters of the forest aboveground biomass stock is in the tropics, this system will prioritize tropical forests.

Just as EO data require expertise and coordinated long-term investment to acquire, process and manage, so do field data. However, while most EO data are acquired by space agencies and then made available to users, there is no equivalent publicly-funded 'ground-sensed' data agency coordinating the provision of *in situ* data to the world. GEO-TREES shall take this role and coordinate the activities required to establish the FBRS and establish a financial framework to support this activity.

The high-quality ground data needed for calibration and validation of EO products are usually acquired by individuals locally and with little support. This contrasts with EO data collection, which is funded wholesale at source by space agencies. While the labour and skill demanded for the groundwork are high, conditions of work are often insecure and difficult. It follows that for *in situ* data to be shared openly it is essential that they be fairly and systematically funded and that adequate provision for training and career development be built into the funding model rather than treated as an optional add-on. *The success of a Global Forest Biomass Reference System will depend on treating those who originate its data as equal participants in the endeavour.* For field data to become open data, they must first be fair data.

2.2 Planned outputs

The goal of this activity is to set up a long-term global reference system of *in situ* forest measurement sites. These standardized measurement sites share a common standard for high-quality data acquisition, with transparent measurement protocols, a long-term monitoring strategy, and measurements traceable to SI units. These sites are called Biomass Reference Measurement sites (BRM).

BRM sites are selected based on their ability to meet the following measurement requirements: (1) Availability of at least 10 1-ha permanent sampling plots, established following the best forestry standards (each stem is mapped, identified, and its diameter measured); the plots must have been inventoried on a regular basis in the past and be accurately geolocated; (2) Potential for airborne lidar scanning (ALS) coverage over at least 1000 ha, flown over the permanent plots; capacity to conduct new airborne lidar scanning coverage on a regular basis; (3) Potential for terrestrial lidar scanning (TLS) of a subset of the sampling plots; (4) Availability of a weather station and automated soil moisture monitoring (ideally encompassing the landscape-scale variation of soil moisture).

Essential for a precise estimation of aboveground biomass, trees monitored in permanent sampling plots should be identified to the species level. In addition to increasing the quality of

aboveground biomass estimates, this information will be directly relevant to the GEO-BON initiative.

The spatial and environmental coverage of 100 BRM sites is necessarily limited. We will additionally define extra low-cost but highly-distributed BRM sites. These distributedBRM sites comprise just single or a few long-term 1-ha plots, and no upscaling using ALS. They do not require the long-term infrastructure of BRM sites, nor do they need a high local density of permanent plots, but provide much better strategic gap-filling than is otherwise possible. Preliminary cost-benefit analyses suggest that 210 distributedBRM sites would be needed to optimally fill the large gaps between tropical BRM sites, and achieve an overall tripling of the tropical site sampling intensity.

Thus, we propose that the FBRS will be centered on 100 BRM sites around the world, with strong priority placed on the tropics, and 210 distributedBRM sites. It is suggested to build on established sites and to complement existing measurements with those required by the CEOS LPV protocol. At these existing sites, landscape-scale biomass estimates can be implemented by combining existing infrastructure and experienced personnel with new investments and complementary observation types such as terrestrial laser scans (TLS), airborne lidar (ALS) and drone-based lidar. Critically, these add insights into tree structure and permit the necessary upscaling to convert the highly localised tree-by-tree and species-by-species perspective of plots into landscape-level reference data. Thus, by integrating the strengths of different technologies, the BRM sites will upgrade the value of forest ground plots for biomass observation and mapping.

2.3 Actual and intended users

The primary user group will be the Earth Observation community, more specifically the biomass measurement community. But the use of the collected data will go far beyond the EO communities. It will directly benefit the ecological and forest science communities, biodiversity research, and the carbon and earth system modelling communities.

3. Background and Previous Achievements

This community activity builds on a series of actions and developments conducted in 2020. Most prominently the EO and ecological communities jointly established the CEOS LPV biomass protocol. This protocol is due for endorsement by CEOS in March 2021. It has been established and is supported by a large research community representing the main academic institutions in forest ecology. Building upon the protocol a subgroup of the writing team of the CEOS LPV biomass protocol drafted an implementation plan for the FBRS. This implementation plan provides a first draft on the cost, potential sites and funding schemes for the FBRS.

A guiding principle of the FBRS is to build on what already exists. First, and most important, are existing international networks of high-quality forest plots in which established protocols are used, consistent training can be done, and skilled scientists are involved. The coordination of the world-wide sites making up these efforts is currently mainly based in Europe (e.g. ForestPlots) and the U.S.A. (e.g. ForestGEO). Close ties to these networks have been established during recent years and representatives of these networks are actively involved in the creation of the FBRS.

Driven by the need to validate the aboveground biomass estimates from the ESA-BIOMASS mission, a seed investment by ESA in a Forest Observation System[1] (FOS) has collated some historical ground-based data from these networks and set up an infrastructure to openly share ready-to-use plot aggregated data. FOS could in future evolve to the GEO-TREES portal,

[1] https://forest-observation-system.net/

hosting the FBRS data in a ready-to-use plot aggregated format for the use by the EO community.

4. Key Activities

Activities in the period 2021-2022 will focus on:

1. Set up the GEO-TREES activity, in particular establish the structure of the project, the governance model and refine the work programme for the coming two years.
2. Identify and reach out to potential partners to support a GEO-TREES coordination office. In the initial phase we anticipate a required funding of ½ a person-year for executive support. The initial phase is set for three years, extending the 2021-2022 work programme of GEO to cover the project up to the launch of the ESA-BIOMASS and NASA-ISRO NISAR missions.
3. Consolidate an implementation plan and funding roadmap for the *Forest Biomass Reference System*. This roadmap will be based on a proposal for creating the *Forest Biomass Reference System,* recently prepared next to the CEOS LPV cal/val document for biomass[2].
4. Link the activity with the GEO GFOI (regarding forest biomass activities) and GEO-BON (regarding forest biodiversity activities) Flagships.
5. Identify and reach out to potential funding partners and seek systematic funding for the *Forest Biomass Reference System*.

5. Relationship to GEO Engagement Priorities and to other Work Programme Activities

Contribution to SDG targets

GEO-TREES in combination with Earth Observation infrastructures will contribute to a number of SDG targets by providing validated global forest biomass maps. In addition, including existing networks as key stakeholders will foster the collaboration and knowledge transfer between engaged countries and organizations. In particular, GEO-TREES will contribute to the SDG goals 15.1, 15.2, 17.6, 17.16, 17.18.

Contribution to the Paris Agreement targets

GEO-TREES will directly contribute to the National Reporting / Global Stocktake pillar according to Article 4 paragraph 2 and Article 14 of the Paris Agreement by enabling the production of verified and validated global biomass maps.

Contribution to existing GEO Flagships, Initiatives and Community Activities

Most relevant to the GEO-TREES activity are the **GFOI** and **GEO-BON** Flagships. A close collaboration with both Flagships has been identified as highly desirable and will be actively promoted by GEO-TREES. It will be a task of this activity to work out a roadmap on the engagement and the level of collaboration. The mission goals of GFOI and GEO-BON provide a first view on a possible collaboration

GFOI is a partnership of countries and institutions that collaboratively assist developing countries for the purposes of reporting for REDD+ results-based payments, monitoring progress towards meeting their Nationally Determined Contributions (NDCs) under the United

[2] Chave, J., Phillips, O., Duncanson, L., Davies, S., Scipal, K., Labrière, N., Saatchi, S., Schepaschenko, D., Quegan, S., Forest Biomass Validation Strategy, Proposal for the creation of a Forest Biomass Reference System, v1.0, 2020-12-16.

Nations Framework Convention on Climate Change (UNFCCC), reporting for the World Bank's Forest Carbon Partnership Facility (FCPF) and other performance-based funds, informing the Global Forest Resources Assessment (FRA), building capacity for national GHG inventories and other country needs. While GFOI's focus is at large on forest observation based on well-established operational techniques with the goal to support international reporting obligations, GEO-TREES will focus solely on the biomass estimation question. The GEO-TREES objective will hence extend on the GFOI objective by integrating forest biomass estimates observed at large in-situ research plots with the latest generation of ground, airborne and spaceborne sensor technologies such as terrestrial and drone-based laser scanning, spaceborne low frequency SAR and lidar. As such, GEO-TREES can contribute to the GFOI objective by providing ground-based forest observations that are critically needed for verifiable and consistent measures of forest biomass.

The GEO-BON objective is to improve the acquisition, coordination and delivery of biodiversity observations and related services to users including decision makers and the scientific community. GEO-TREES can contribute to this objective by providing a global database of forest tree species observations. In return GEO-TREES can benefit from the GEO-BON partner network and expertise.

6. Governance

We anticipate a slim and as horizontal as possible governance model for GEO-TREES. The activity shall be implemented by a **project executive**. It will be the first task to nominate a person for this role and to acquire financial support for this position. Until an executive is nominated, Klaus Scipal will act as focal point for organisational and communication matters with the GEO secretariat.

The executive will be supported by a **steering committee**. The steering committee will act in two roles. First, the steering committee will meet regularly to decide on the workplan and to control and endorse related activities and guiding documents. Second, during the initial phase, individuals of the steering committee will support the executive to implement the activity and execute related tasks. During the first phase the steering committee will be composed of the authors of the *Proposal for the creation of a Forest Biomass Reference System*: Jerome Chave (Laboratoire Evolution et Diversité Biologique, France), Oliver Phillips (University of Leeds, UK), Laura Duncanson (University of Maryland, USA), Stuart Davies (Smithsonian Tropical Research Institute, USA), Klaus Scipal (European Space Agency, Italy), Nicolas Labrière (Laboratoire Evolution et Diversité Biologique, France), Sassan Saatchi (Jet Propulsion Laboratory, USA), Dmitry Schepaschenko (International Institute of Applied System Analysis, Austria), Shaun Quegan (University of Sheffield, UK) and Mat Disney (University College London, UK).

Finally it is planned to establish a **PI forum**. This forum will comprise a representative of each reference site and should foster the engagement of those communities in the evolution of GEO-TREES.

One of the tasks during the first year will be to implement this governance structure, and refine the roles and responsibilities of the different bodies.

7. Data Policy

GEO-TREES will follow a strict open data policy. **Data will be free at the point of access, and fair in the process of acquisition.**

Tree-by-tree records acquired from long-term plots require a series of skilled and laborious activities. These are hard-won data, collected by experts who will not be replaced by

technology in the foreseeable future. As this is an intensely human process it follows that a number of conditions need to be met for high-quality ground data to become fully open to all. Particular support is needed in the tropics because this is where most biomass, tree growth, and diversity is located, and this is where long-term security for measurements and the people who make them is lacking.

Currently, individual research teams and field workers typically need to organise (and fund) their own data acquisition and pre-processing, and this makes the process piecemeal and insecure. Further, especially in the tropics again, many doing this work are disadvantaged by location, ethnicity, education, working conditions, and access to funding, compared to those in the user community. Acknowledging these structural inequalities is essential for our plan for globally-coordinated acquisition and provision of ground data to be successful, sustainable, and inclusive.

The prerequisite then to open data for tropical trees, species and forests is to properly value and invest in the people and skills needed to acquire and manage ground data, as well as the actual data measurement and management activities themselves. Thus, for GEO-TREES to be open and free at the point of access it is essential that the whole process of data origination is fairly and properly funded.

Annex A

Contributors

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