

FROM TREE MEASUREMENT TO NATIONAL FOREST MONITORING SYSTEMS

The use of allometric equations
to estimate forest resources



QUANTIFYING FORESTS

Allometric equations are important tools for quantifying forest resources. The UN-REDD Programme promotes the use of these equations for estimating national carbon stock and carbon stock changes as part of the development of their national forest monitoring systems (NFMS) as required under REDD+. The Programme supports countries around the globe to develop equations and define methodologies for their application by providing expert guidance and country-level capacity building.

Achievements since 2012

13 training workshops in **13** different **countries**

Over **350 participants trained** in allometric equation development,
22% of which were **women**

The **GlobAllomeTree web platform** contains over
12,000 equations which cover all forests in all continents

Over **1 600 registered users** of GlobAllomeTree database,
and over **70,000 pageviews**

18 papers/manuals published on **allometric equations**

More than **10 partnerships established** with
top international forestry institutions and universities

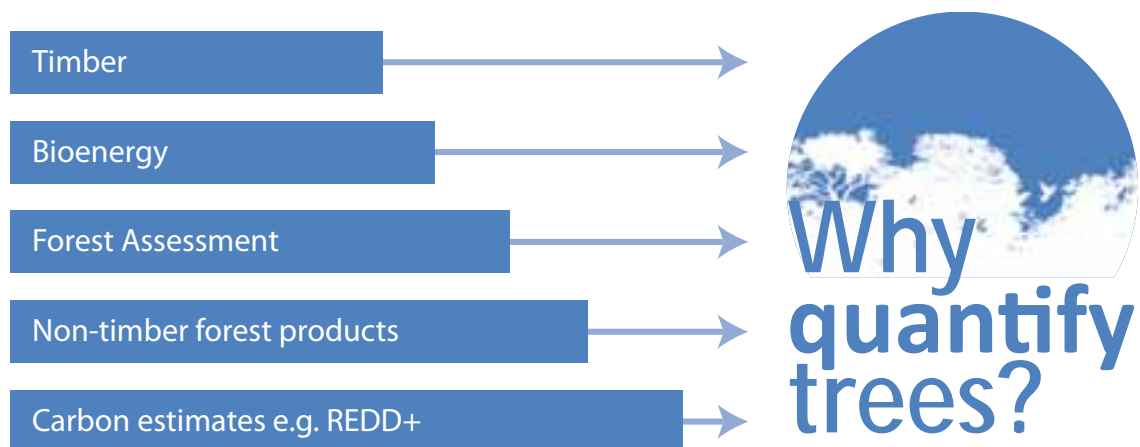
More than **100 scientists** and **national experts** have been
brought together during workshops to **improve data-sharing** and
knowledge exchange

What are allometric equations and why are they useful?

Allometric equations are statistical models that are used to express the relationships between the different components of a tree (such as stem, roots and branches) in terms of their relative sizes.

They allow foresters to convert simple measurements of trees such as stem diameter to characteristics which are more difficult to measure such as volume, biomass and carbon stocks, minimizing the need for expensive and time-consuming destructive measurement of trees. For example, the application of an appropriate allometric equation allows the estimation of total forest carbon stock from a simple collection of data on tree diameters in a forest plot.

Errors and uncertainties in the application of these equations to individual trees often propagate to errors at the forest and country level when estimating forest carbon stock and carbon stock changes. The development and use of country, biome, climate and species-specific equations improves accuracy, minimizes error propagation and reduces bias arising from the generalizations produced by using a generic equation.



GlobAllomeTree: global data sharing and support

Archiving, sharing and harmonizing data among stakeholders allows the replication of analyses, ensures transparency and consistency of measurements, saves time and resources and improves data reliability.

- » The GlobAllomeTree platform was launched in 2013 by the FAO, the Forestry Department of the University of Tuscia and the French Centre for Agricultural Research for Development (CIRAD).
- » Currently the platform contains over 12,000 equations covering all contextual and statistical needs. These data contribute to the IPCC emissions factor database.
- » The database has over 1600 registered users from over 100 different countries, with over 70, 000 pageviews since its launch.



www.globallometree.org



Country context for allometric equations

The UN-REDD Programme adapts its national support to country needs and capacities in order to build a multipurpose and sustainable NFMS.

Issues that need to be considered when implementing allometric equations and their development in a country include:

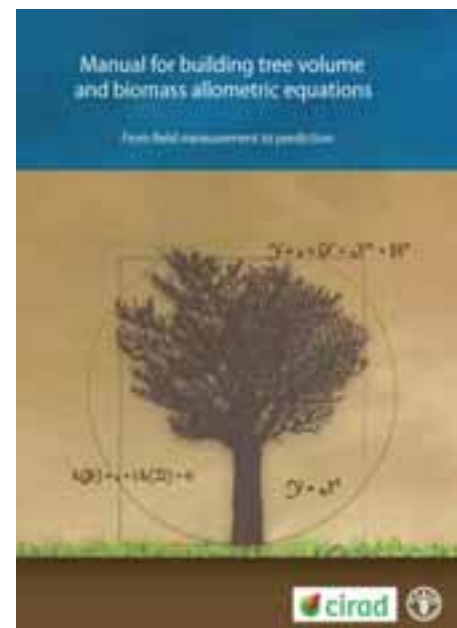
- » *Data-access:* national forest inventory and allometric model data may not be accessible at the country level due to lack of a framework for equitable data sharing, finance or a network of supporting technical experts and forestry institutions.
- » *Capacity for data collection, archiving and analysis:* some countries may not have the financial or technical capacities, or may lack a procedural framework for the collection and management of data on forests.
- » *Specific environmental context of each country:* countries containing tropical rainforests have high biodiversity but also often lack the resources to develop adequate equations compared to countries in temperate zones. Other countries may not be heavily forested but instead contain many trees outside of forests which need to be accounted for such as in home gardens, agroforestry, agricultural land and urban zones.
- » *Different national objectives and policies:* countries have different motives, priorities and goals for quantifying their forests.



Building capacities: training according to country needs

The UN-REDD Programme's approach to capacity building is adapted to each country's needs in order to support knowledge transfer and sustainability of the national forest monitoring system.

- » Country capacity is assessed and basic technical trainings are held targeting relevant stakeholders and institutions. A core team of motivated sector technicians are identified from each of the key national forestry institutions and the data necessary for equation development is determined.
- » A set of technical training modules has been developed covering all aspects of equation development for forest assessment. The training begins with understanding basic statistics, software, forest ecology, tree biomass allocation, forest stratification and methods and good practices suggested by the Intergovernmental Panel on Climate Change (IPCC). It progresses through practical trainings on destructive and semi-destructive sampling, laboratory analyses, allometric equation building, data entry, analysis and modelling. The final most advanced modules focus on assessing error and uncertainty propagation.



www.fao.org/docrep/018/i3058e/i3058e.pdf



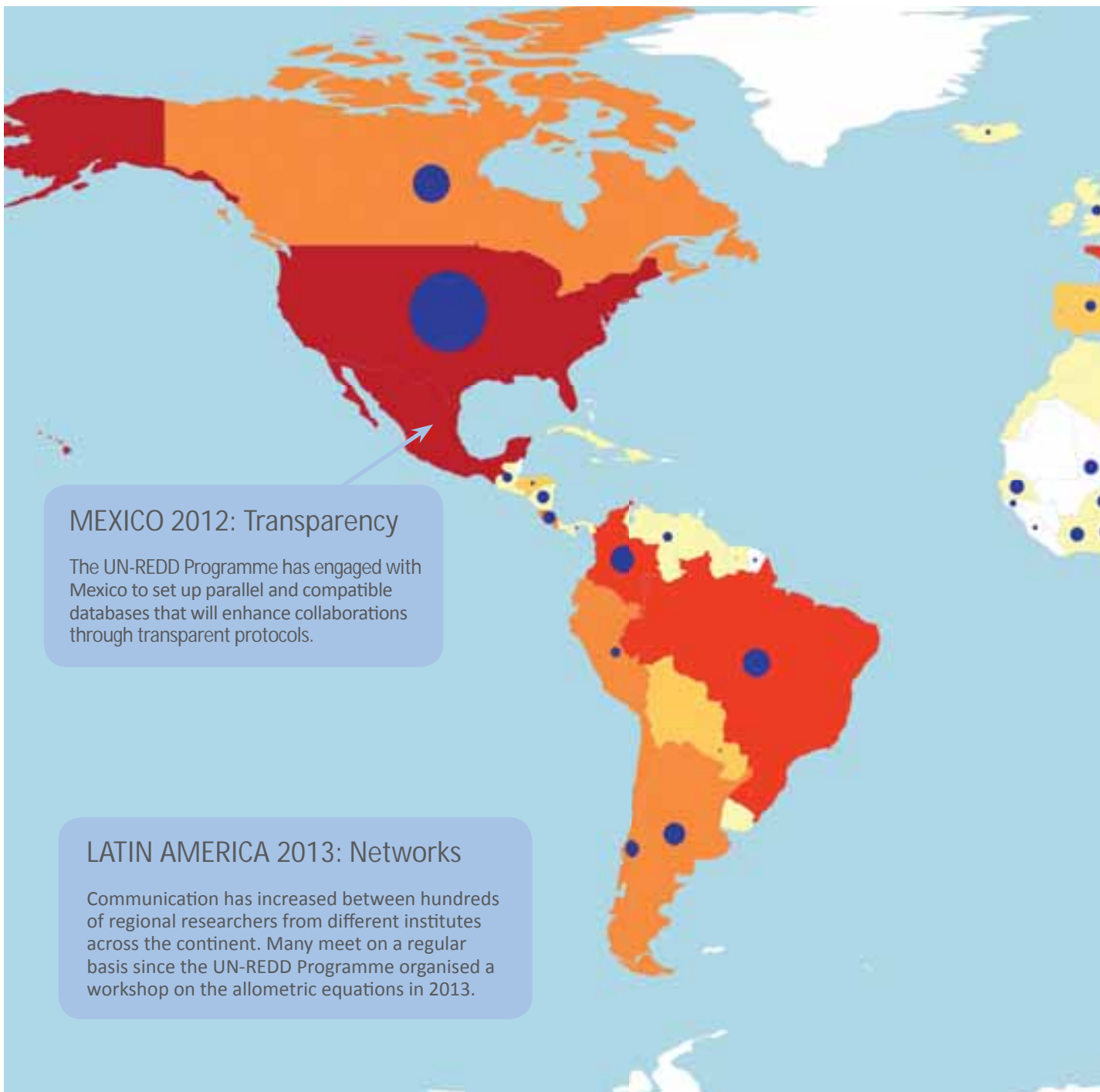
UN-REDD Programme's stepwise approach to country capacity building on the development of allometric equations

The Programme has produced 18 publications to support knowledge transfer and transparency, such as manuals and tutorials on the development of allometric equations and on database usage. Refer to publications list. The use of open-source/freely available tools is promoted while no single software is favoured over another.



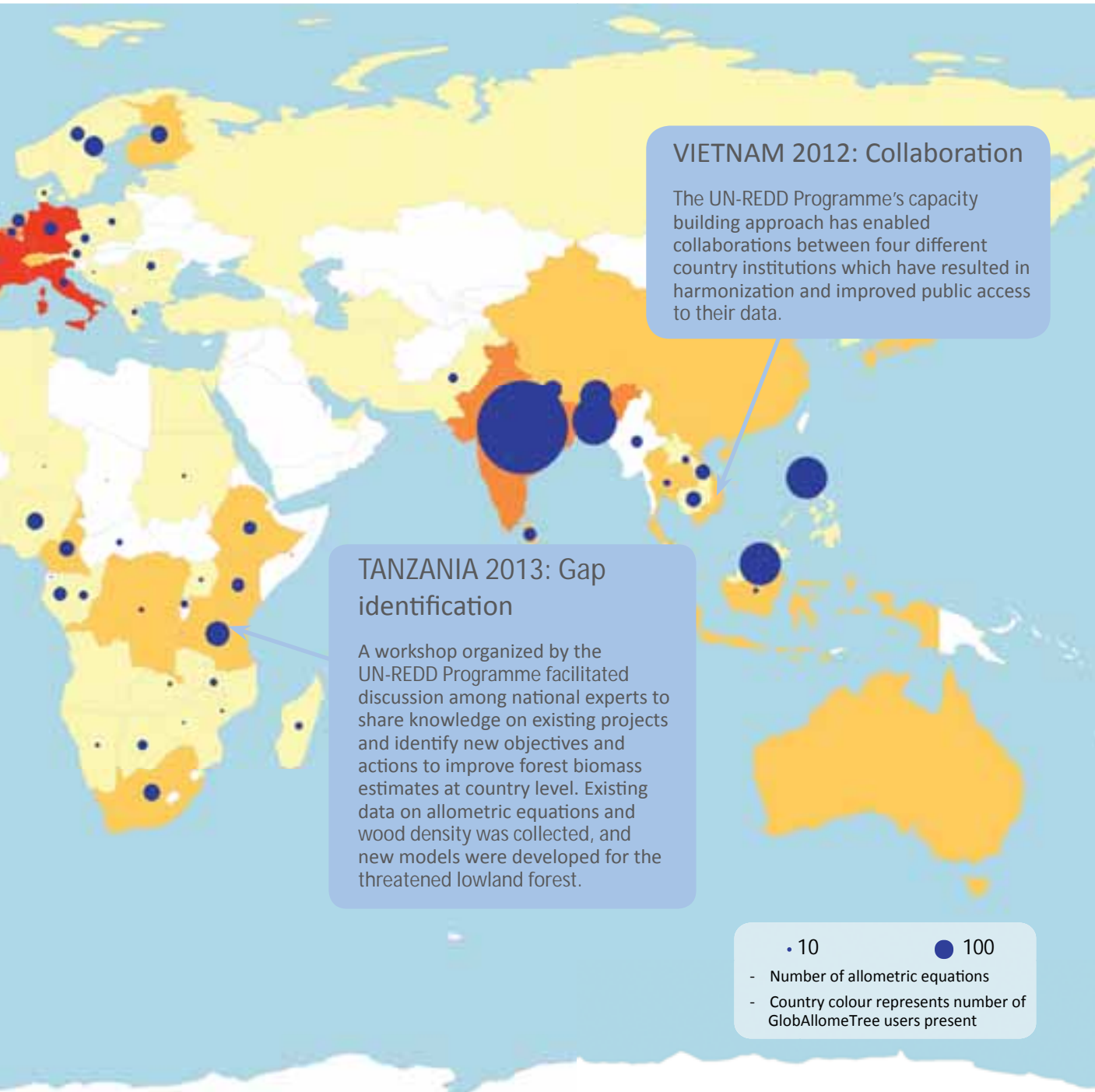
Establishing partnerships

The UN-REDD Programme has partnered with numerous national and international institutions involved in forest assessment. These include the Tropical Agricultural Research and Higher Education Centre of Costa Rica (CATIE), the Kerala Forest Research institute (KFRI) and the French Centre for Agricultural Research for Development (CIRAD).



across the globe

The FAO acts as a catalyst enabling the sharing of data and equations between partners. These partnerships are spreading across the world.



MEXICO 2012: Transparency

Mexico is one of the leaders in the implementation of NFMS in Latin America, and a centre of excellence for South-South cooperation. A workshop was held in Guadalajara and attended by both national and international experts to discuss and improve Mexican methodology for forest biomass and uncertainty assessment. Collated national allometric equations, and a number of decision trees designed for selecting optimal tree biomass equations were published through an open access web platform. The dissemination of these decision trees improved consistency among allometric equation users and semi-automated biomass and carbon stock assessment in Mexico. Data-sharing between the FAO and the national forestry commission of Mexico (CONAFOR) will promote data transparency and ensure compatibility and collaboration between the Mexican national database (www.mrv.mx/modelosalometricos) and GlobAllomeTree.



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VIETNAM 2012: Collaboration

Seven groups from four Vietnamese forestry institutions attended the UN-REDD Programme's training workshop on allometric equations. A public database was created containing existing allometric equations, volume tables, species lists and data on wood density and biomass. Harmonized national technical guidelines for field measurement were agreed on and used to collect data for the calculation of new models, which extended the range of coverage to all Vietnamese eco-regions. The four institutions have collated their data into one common template using the same software to ensure comparability and consistency. They are working together to develop a new set of national-level equations as well as a single national decision tree to select optimal equations per region of the country. The institutions have also opened access to the wood density database via a harmonized template.



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TANZANIA 2013: Gap Identification

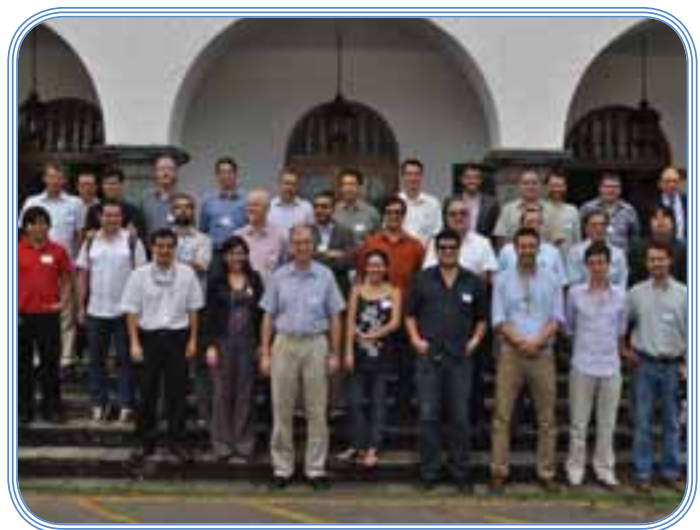
National experts and university students involved in the development of allometric equations attended a meeting to highlight the work that has been done so far, assess the gaps remaining and define a series of activities to improve national biomass estimates. It was proposed that public databases should be built from previously published Tanzanian equations and wood densities. Projects to gather field data should be supported in order to develop new equations particularly for the threatened lowland forest. A new set of equations was developed for this forest type, while parallel projects focus on the other important forest types of Tanzania.



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LATIN AMERICA 2013: Networking

Research groups collaborated to compile a database of all available allometric equations for South and Central America. Hundreds of research and academic institutions, individual researchers and forestry officials contributed to the database, available internationally via GlobAllomeTree. Since its launch, attention to improving the availability and quality of the equations in Latin America has considerably increased. In 2013, a regional workshop held in Costa Rica was organised to initiate formal dialogue amongst the many individuals and institutions involved in research related to allometric equations in Latin America. The workshop brought together most of the experts from different institutions to identify the gaps in knowledge and needs related to forest assessment in the continent. Prior to the workshop, communication, let alone collaboration between the various stakeholders was uncommon, and cited as a roadblock to progress in equation development.



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MOVING FORWARD

Given the advances made in regards to improvements in forest biomass estimates across countries, UN-REDD plans include harmonizing methodologies, improving statistical methods and data-access, and capitalizing on opportunities to improve estimation through the use of new technologies. This section outlines how the Programme is moving forward in response to the gaps identified and recommendations received from the partner countries.

1 Improve data-sharing

The UN-REDD Programme is improving the development of reliable frameworks for data ownership and sharing that include transparent rules, standardized sharing procedures and the actual platforms and software used for sharing and archiving data.

- » Institutional cooperation and the sharing of data and information.
- » Research institutions should be encouraged and collaboration facilitated by incentivizing data-sharing. Additionally incentives and policies could be applied where technical, human and financial capacities limit data collection, analysis, review, scientific publishing and sharing.

2 Ensure adequate reporting of biomass functions

The UN-REDD Programme is maintaining and expanding a global network of partners and a global database to standardize procedures related to the assessment of forests.

Biomass functions such as allometric equations should be reported in such a way that they support UNFCCC's recommendations for transparency, accuracy, consistency, comparability and completeness.

- » Procedures for the collection of the data used to develop allometric equations should be standardized and readily available. Tree components, size variables and methods for sample collection, tree communities and environmental and climatic conditions must be clear when reporting sampling methods.
- » Clear descriptions of methods, tools, software and calculations used for data and laboratory analyses will allow replicability, and well documented data, metadata and the model fitting process used allow validation and further development of equations.

3 Refine the selection of allometric models

The UN-REDD Programme is developing new statistical methods while increasing global access to existing models. Future developments aim towards using non-destructive measurements such as remote-sensing while reducing uncertainty.

Since inadequate selection of models can result in large errors in the estimation of forests, uncertainties in the selection of models need to be resolved.

- » A transparent approach is to compile all available equations and construct decision trees specific to the objectives of the project to determine which equation is optimal based on the lowest uncertainty relative to direct measurements of field data. The use of decision trees helps to remove subjectivity from model selection.
- » Bayesian model averaging has been identified as a promising ensemble approach that allows different models to be combined into a single predictive model. It incorporates uncertainties into the model and increases the transparency of the estimates.

4 Utilize new technologies and methods for forest assessment

The UN-REDD Programme is currently exploring the integration of allometric equations and remote-sensing technologies to improve large-scale estimates of forest stocks. It also works in parallel with countries to satisfy their capacities regarding big-data availability and cost, archiving and database sustainability.

New technologies and methods allow improvement of forest assessment in a number of different ways although many of these new technologies are costly or still experimental..

- » Remote-sensing technology can be used to estimate forest area and biomass and help in the design of sampling procedures.
- » LiDAR-based technology increases the capacity to generate large-area, non-destructive estimates. Ground penetrating Radar can be used to estimate under-represented and currently cost-ineffective below ground biomass estimates.
- » However, national technical, financial and human capacities must improve to sustainably support countries to update available technologies. Large amounts of data require archive and institutional permanence and stability.

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UN-REDD PROGRAMME



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