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Global Forest Resources Assessment 2015: What, why and how? ☆

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ABSTRACT

This paper introduces a Special Issue of Forest Ecology and Management that includes a collection of analytical results from the 2015 Global Forest Resources Assessment (FRA 2015) covering 25 years of forest change (1990–2015). FRA 2015 builds on a series of global assessments that began in 1948 and covers change in forest area and type, volume, biomass and carbon stocking, measures of sustainable forest management, biodiversity and conservation, soil and water protective functions, wood production and a number of socio-economic variables. It covers 234 countries and territories with an emphasis on forest resource change over a twenty-five year period (1990–2015) and also looks forward to anticipated forest change – both as government targets for forest area and projected change (to 2030) to global production and conservation forest area (to the year 2050). This paper describes important contributions of global forest resource estimates to forest management, the methods used in the collection and analysis of FRA 2015 data and provides links to additional information resources. It discusses some of the limitations of this global dataset, some of the steps taken to improve quality and the characteristics that make this type of global data most useful. While forest area change dominates public use of the FRA, the state of the forest resource and management is critical to understanding the ecological and social values of the forest and forestry. Country level reporting not only provides insights that are only possible through national reporting but also provides greater national-level understanding and discussion of forest resource change. The papers that follow in this Special Issue provide analyses of FRA 2015 data covering a wide range of topics related to sustainable forest management and forest change.

1. Introduction

1.1. A short history of global forest resource data

We often take for granted our global knowledge of forest resources. Yet it is only since the 1920s that humankind has had any real understanding of the global forest resource. That knowledge has changed the shape of how forests are viewed by the public – and it has influenced the investment of public and private money in forestry.

Global information on the extent and quality of the forest resource did not exist until Rafael Zon and Sparhawk (1923) produced the first comprehensive Global Forest Resources Assessment in 1923. This ground-breaking work set the stage for all future global forest assessments and was a remarkable accomplishment in the aftermath of World War I. The assessment did not include all countries and as a result reported world forest area as just over 3 billion ha.

The first global assessment conducted by the Food and Agriculture Organization of the United Nations (FAO) was published in 1948 when the main interest was well expressed in the first sentence of the report: "The whole world is suffering from shortages of forest products" (FAO, 1948).

Global Forest Resources Assessments, coordinated by FAO, have been made at approximately five to ten year intervals since then. The mandate for these assessments is found in the FAO Constitution, which states that "The Organization shall collect, analyze, interpret and disseminate information relating to nutrition, food and agriculture. In this Constitution, the term 'agriculture' and its derivatives include fisheries, marine products, forestry and primary forestry products." (Article I, Functions of the Organization, paragraph 1).

The scope and content of global forest assessments have evolved over time to respond to changing information needs. Studies of timber supply trends dominated the assessments through the 1960s, but from the 1980s onward they have included a wider range of forest benefits and functions. The challenges faced in global forest assessment begin with a persistent lack of reliable source data to meet increasing demand for information. For example, the 1992 Earth Summit in Rio de Janeiro initiated three

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conventions (UN Framework Convention on Climate Change, Convention on Biological Diversity and the UN Convention to Combat Desertification) that each have expanded requirements for countries to report on forest resources. Organizations and technical professionals seek new global information through the FRA and this interest often translates into new areas of inquiry, despite efforts to keep the assessment focused on the forest resource. This demand for information has been difficult for countries to meet in large part because the data often do not exist and resources for additional data collection are scarce.

Criticisms of FRA data have been primarily focused on data-poor country reports, the lack of comparable long-term trend data (Mather, 2005; Grainger, 2008; Harris et al., 2012) and assumptions that suggest remotely-sensed data are inherently superior to forest statistics reported by sovereign nations (Grainger, 2008; Harris et al., 2012; Hansen et al., 2013). While the idea of long-term, high quality forest data collected using the same methods across time, forest type and countries with highly divergent access to technical and financial resources is attractive, it is also most impractical. At the same time, the assumption that remote sensing provides clear, accurate and precise results for forest change at the global scale is also tenuous. Recent attempts to report global forest change have made the mistake of characterizing tree cover change from satellite imagery as forest change (Harris et al., 2012; Hansen et al., 2013) without regard to the processes of natural regeneration and reforestation. Both of these studies have confused the distinction between forest and woody horticultural crops and as a result reflect tree canopy change, but not necessarily forest change. Neither remote sensing nor country-based reporting provides perfect answers to forest resource change questions. An analysis of how results from FRA 2015 and remote sensing studies compare is found in Keenan et al. (2015).

Global Forest Resources Assessment (FRA) 2015 statistics and analyses reported in this volume inherit many of the same strengths and weaknesses as the 1948 assessment, yet it is also a very different assessment in scope, transparency and quality. More national forest inventories were available for FRA 2015 than for any other global assessment – 70% of them utilized remote sensing for at least a portion of the inventory. In 1948, one hundred and one countries and territories reported – in 2015, this increased to 234 countries and territories.

While public interest in forest change presently seems focused on deforestation, many of the world's forests have changed in other important ways that are less visible to the public – for example characteristics such as stocking density, species composition and diameter distribution (Plumptre, 1996; Dallmeier and Comiskey, 1998; Coomes and Allen, 2007). Climate change is predicted to create substantial shifts in tree species distribution and forest structure (Scheller and Mladenoff, 2005; Gustafson et al., 2010). These shifts may require even greater monitoring efforts to assess more rapid forest change in the future. At the same time, human populations have nearly tripled from 1948 to 2015 and are predicted to continue increasing, putting greater pressure on remaining, accessible forests to provide goods and services for a growing population.

Understanding how global forest resources are changing is far more complicated, and generally far more important than understanding forest area change alone.

1.2. How have FRA global datasets been used?

Information on the global state of forests drives policy and resource flows at global, regional and national levels. Forests today – including extent, composition and structure, are in part a result of the many years spent acting on reported characteristics and forest change. MacDicken (2014) highlights how, for example, past FRA reports noted the rapid conversion of broadleaf tropical forest into agricultural land. This helped prompt some 60 years of increased investment by governments, companies, individuals, donor agencies and civil society groups in improving forest management in the tropics. This investment has in turn contributed to the reductions in tropical forest loss rates reported in Keenan et al. (2015) and FAO (2015).

Forest stock losses due to long-term land use change, especially in the tropics, are an important part of greenhouse gas emissions (Settele et al., 2014). Forest area and growing stock changes detected through monitoring have provided improved understanding of forests in the global carbon balance – and much of the early work on this topic came from the FRA (Detwiler and Hall, 1988; Houghton, 2008). FRA data continues to be used in global estimates of emissions from land use and land use change for the Intergovernmental Panel on Climate Change (IPCC) and climate change modelling (Smith et al., 2014; Petrescu et al., 2012).

Global reporting over time can help identify knowledge gaps and highlight where improved information on forest resources is needed. The importance of field-based National Forest Inventories (NFI) has long been demonstrated through FRA reporting – both through the value of reported inventory results and the identification of serious data gaps in countries where these inventories do not yet exist. The FRA 2015 dataset adds value to NFI results by providing a Tier system that integrates data age and source classes. The need for updated field-based forest inventory has become increasingly important for climate change mitigation efforts such as the Reducing Emissions from Deforestation and Degradation (REDD+) mechanism.

The inclusion in FRA global reports of earth observing satellite data such as those obtained and derived from the Landsat sensor have become a useful adjunct to country reporting on forest extent over time. The integration of Landsat in tracking forest cover change in the tropics (FRA 1980, 1990, 2000) has helped highlight the global value of this unique dataset. At the same time the use of remote sensing in national forest inventories on which many FRA country reports are based has grown substantially (MacDicken et al., 2015).

2. Methods

2.1. Characteristics of FRA 2015

FRA 2015 was organized around 21 key questions grouped into eight topical categories: forest area and forest characteristics, production, protective functions and ecosystems services, biodiversity/conservation, disturbance, measuring progress toward sustainable forest management, economics/livelihoods and looking forward (www.fao.org/forestry/FRA2015/Methods). A total of 117 variables are included, most of which covered the period 1990–2015 (Table 1). FRA 2015 included 37 variables that were not included in previous assessments. Countries submitted reports between October 2013 and July 2014, including projected values for the 2015 reporting year.

The majority of variables were reported for the years 1990, 2000, 2005, 2010 and 2015. Future forest area targets were requested for the years 2020, 2030, and some variables were requested for the latest available year when a specific date was likely to be unavailable or irrelevant (e.g., monitoring of forest management plans stakeholder involvement). In addition to the quinquennial reports, annual values were reported for wood removals, total burned area and burned forest area. Annual forest area under international forest management certification were provided by the Forest Stewardship Council (FSC) and Programme for the Endorsement of Forest Certification (PEFC). Projections of future forest area were requested of countries for 2020 and 2030 and a

Table 1
Summary of FRA 2015 characteristics.

Characteristic	Values
Proportion of forest area covered by country reports	98.8%
Proportion of forest area covered by FAO desk studies	1.2%
Number of questions	21
Number of variables	117
Reporting periods[a]	1990, 2000, 2005, 2010, 2015, 2020, 2030, latest available year
Proportion of variables covered by Tier categories	33%
Number of capacity building workshops/participants	22/591

[a] Reporting periods were variable-dependent (see online methods document for reporting years by variable).

special study was conducted using a scenario-based model to project possible forest change to the year 2050 (D'Annunzio et al., 2015).

The dataset available online at (www.fao.org/forestry/FRA2015/dataset) contains quantitative data and Boolean expressions plus descriptive data covering data contributors, original data sources, methods and comments from FRA National Correspondents. Country reports that contain complete country submissions can be found at www.fao.org/forestry/FRA2015/CountryReports. Most countries submitted their reports using an online data entry system (Forest Resources Information Management System – FRIMS) which included automated quality checks for use by National Correspondents and reviewers. Data were extracted into Excel worksheets from the FRIMS for analysis in Excel or specialized statistical software packages.

Countries were provided with pre-filled online reports that included data provided to FAO for FRA 2010 in order to improve consistency and reduce the reporting burden. Countries were encouraged to review these data, and the data from external sources, and to revise them for previous years (1990–2010) if more recent or higher quality data were available. These updates can be a source of confusion because they may result in different values for the same reporting year in two different assessments. Grainger (2008) notes the difficulty in using FRA data for assessing long-term trends in part because the values are adjusted by countries over time. Because the most recent reporting year for forest area in each FRA is projected rather than measured, it is inevitable that the measured values reported in a subsequent assessment will be different from the projected values in the preceding assessment. In addition, new inventories or remote sensing results or correction of previous errors result in new values for previous reporting periods.

While this Special Issue describes many of the most important changes in forest extent and quality over the period from 1990 to 2015, it does not provide exhaustive analysis of many FRA variables. Additional FRA 2015 reports include a synthesis document (www.fao.org/forestry/FRA2015/Synthesis) and a Desk Reference that provides summary tables for nearly all of the tabular values in FRA 2015 (www.fao.org/forestry/FRA2015/Desk Reference). Readers are encouraged to download and explore the data (www.fao.org/forestry/FRA2015/Database). This online database also provides access to country data from related areas such as agriculture, demographics and others to allow analysis of FRA results together with non-forest resource data. All of the papers in this volume use the FRA 2015 data set as a primary source and in some cases are supplemented with additional data from other sources.

Individual papers in this volume describe methods used for each paper. For general methods used in the FRA 2015 data collection process and definitions (including additional details on the categories below), please see: http://www.fao.org/forestry/FRA2015/Methods.

2.2. The primary analytical categories for FRA 2015 data analyses

2.2.1. Global

Global analyses of FRA 2015 data are possible for up to 234 countries and territories. The number of reports per variable and the number of variables reported per country differ widely. In general, country reports contain more data than desk studies. Missing values present a challenge in interpreting FRA data at the global level – particularly in cases where countries report on variables for some years and not others. Addressing missing values without losing important information is difficult for this data set and there is no perfect solution. For FRA 2015 no missing values were filled in by FAO. Authors in this volume have chosen analytical approaches to handle missing values based on their judgement of the extent and nature of data gaps.

2.2.2. Sub-regional

FRA 2010 primarily used five geographic regions to break down global trends. FRA 2015 uses 12 sub-regions for finer-scale global analyses and provides for regional analysis using FRA-designated regions. Sub-regions are particularly important where intra-regional trends are markedly variable – for example, the region of North America includes Canada, Mexico, the United States and the countries of Central America. In the sub-region of North America forest area is increasing and the sub-region of Central America forest area is generally decreasing. Similar trends are found in Asia when aggregated at the regional scale. Use of the sub-regional scale provides greater analytical sensitivity than use of the regional scale.

2.2.3. Climatic domains

Climatic domains are used in FRA 2015 as a categorical variable in the analyses reported in the Special Issue. Because the FRA is not spatially explicit, climatic domains at the national scale are defined by the dominant climatic domain per country. These domains were assigned based on spatial analysis of the forest area in each domain per country using a forest distribution approximation from Hansen et al. (2003) and domain distributions from Iremonger and Gerrand (2011). These describe the following domains as aggregations of ecological zones: Tropical, Sub-tropical, Temperate, Boreal and Polar. For the purposes of FRA 2015 the Polar zone was dropped as forest area is *de minimis* and at the country/territory scale is restricted to Greenland and the Svalbard and Jan Mayen Islands. Because of the lack of spatial data in the FRA, the climatic domains should not be perceived as precise delineations. A spatial analysis of mapped forest by ecozone would differ from those presented in this volume because of the presence of multiple climatic zones within some large forest area countries (e.g., Canada, China, Australia, and the United States). However, analysis of predominant climatic domains does provide a useful approach of discriminating and understanding where forest area change occurs.

2.2.4. Income categories

Gross National Income per capita was used as a categorical variable with four income categories defined by the World Bank (http://data.worldbank.org/about/country-and-lending-groups): Low-income economies ($1045 or less), Lower-middle (US$1046–$4125), Upper-middle (US$4126–$12,745) and High income economies (US$12,746 or more). No adjustment of these categories were made – although there were fifty-five countries or territories used in FRA 2015 (out of 234 countries and territories) that are excluded in the World Bank categories. These countries/territories represent 9.1 million ha of forest that is not included in the income category-based analyses. Analyses by income category provide unique insights into where forest is concentrated, where change is occurring and where the challenges for sustainable forest management are greatest.

2.2.5. Country report vs. desk study

While the FRA process is dependent on national reporting by governments through their designated National Correspondents, not all countries/territories have forest or a National Correspondent. FAO received 155 country reports for FRA 2015 – representing nearly 99% of total forest area. When country reports were not submitted, FAO made estimates using desk studies based on available literature and expert estimates – a practice also used in previous assessments. Desk studies are analyses done by FAO staff and consultants based on limited data sources, and are therefore are as a category less reliable than country reports. Desk study countries are clearly identified in country reports, the online database (www.fao.org/forestry/FRA2015/database) and the Desk Reference (www.fao.org/forestry/FRA2015/Desk Reference).

2.2.6. Quality tiers

FRA 2015 used a set of tier categories similar to those used by the Intergovernmental Panel on Climate Change (IPCC). Tiers were requested for all variables that potentially had more than one source of data. Tiers were defined by countries for each of the included variables for both status (i.e. the most recent report) and trend (i.e. for two or more reporting periods). Countries were asked to assign a Tier value to each qualifying variable: Tier 1 (expert estimate), Tier 2 (low intensity or incomplete surveys, older data) or Tier 3 (high reliability, recent sources with national scope). Specific definitions for each tier were provided in the FRIMS following this general pattern and are available in the FRA country reports online. Tier values were requested for status and trend for about one-third of all FRA 2015 variables.

It is important to note that all country reports were independently peer-reviewed by FAO staff, partners in the Collaborative Forest Resources Questionnaire (CFRQ)[1] and external experts. Peer-review comments were provided to National Correspondents for inclusion and, where necessary, corrections of individual national reports were made before incorporation of data into the final FRA 2015 database.

3. Discussion

3.1. When are global forest resource data most useful?

Global datasets are often less detailed and precise than national or sub-national datasets – this is also true for the FRA. Users have through stakeholder discussions, internal FRA evaluations and a user survey noted the following desired characteristics for global forest resource assessments:

3.1.1. Known levels of precision

Understanding the precision of reported values instils an appropriate level of confidence in mean or summed values and allows variance-based analyses. The FRA country reporting process does not produce numbers with measures of variability around reported values. This does not mean, however, that national data necessarily originate from a source without estimates of precision. Indeed, many countries use survey methods capable of generating estimates of key FRA variables along with estimates of precision. The Tier designations provide a measure of relative confidence in data at the variable level, even though measures of precision are not reported. Sample-based remote-sensing values reported at regional, ecozone and global levels (FAO and JRC, 2012; FAO and JRC, 2014) provide added value in that the analysis contains calculated levels of precision around the means.

3.1.2. Consistent definitions over time

Consistent definitions allow better comparisons over time and make reported values more consistent across countries. One of the differences between the assessments done prior to the year 1980 is that they contained a variety of forest definitions. While the pre-1980 definitions essentially defined forests as seen by sovereign states, they resulted in countries reporting to different standards. By the year 2000 definitions of variables such as forest area were stable across all countries and have not changed in the FRA since then. Other definitions have changed, as data limitations were demonstrated or needs or data sources changed (www.fao.org/forestry/FRA/2015/Historicalvariables). Variables included in FRA 2015 were assembled (and for new variables, defined) through extensive consultation with a wide range of experts and stakeholders.

3.1.3. Ease of interpretation

Given the complexity of forests and forest change, no single source of data tells a complete story. Even the definition of forest in the FRA can be difficult to communicate. While the FRA definition of forest may on the surface appear to be a forest cover definition it is actually a forest land use definition – land can be temporarily devoid of tree cover and remain forest land for FRA reporting purposes. This is an important difference between the internationally accepted definition of forest used in the FRA compared to sources such as Global Forest Watch, which reports changes in tree cover of all types. Data that are not easy to interpret are less useful – which requires continuous efforts by FAO and partners to provide easy access, clear definitions and analyses to help inform interpretation.

3.1.4. Reasonable potential for practical use

Many users seek FRA data that has practical use. While much is said about the value of FRA data for policy makers, it is only when forest policy translates into appropriate changes in management practices or investment that positive improvements in forest management occur. This applies to forestry-related investments by governments, private companies, donors, NGOs or individuals. Making global and national-level forest information relevant – and easily accessible – to those who make investment decisions can help improve decision-making and ultimately improve forest management and use.

3.1.5. Process is part of decision-making

FRA 2000 (FAO, 2001) noted that government users of FRA data are most likely to be committed to improving it when they are also responsible as producers of the information. Mather (2005) noted that while the user focus is often on FRA results, the process of planning, data collection and reporting is a potentially significant instrument of forest governance. Countries such as Brazil use FRA reporting periods to assemble and discuss data across government units and in the process learn in ways that might not otherwise be possible (J. de Freitas, pers. comm.). Other countries, such as Canada, Mexico and the United States collaborate with each other in how they report to the FRA to assure more consistent data at the continental scale and adapt some aspects of their data collection to FRA definitions (B. Smith, pers. comm.).

[1] CFRQ Partners share over 50% of FRA 2015 data to reduce country reporting burdens and improve data consistency. Partner organizations are FAO, FOREST EUROPE, UN Economic Commission for Europe, International Tropical Timber Organization, the Montreal Process and the Observatoire des Forêts d'Afrique Centrale.

3.2. Challenges with the FRA data include

Despite efforts since 1948 to improve reporting and data quality there remain constraints to the use of FRA data (FAO (1948, 2010), Grainger (2008), Harris et al. (2012)). The following section outlines some of the known limitations of the data collected for FRA 2015.

3.2.1. Incomplete country reporting

The FRA 2015 questionnaire contains a diverse range of requests. In most cases, countries are unable to complete the entire questionnaire for all years requested. Missing data complicates time series analysis, particularly those that relate to forest area numbers and requires caution in analysis and interpretation. This problem will persist in future assessments because – like optical satellite imagery in areas of perennial cloud cover – data in some countries simply do not exist.

3.2.2. Inaccurate reporting

Until FRA 2015, there was no way to assess reporting quality without reading individual country reports. In 2015, the tier system described in this paper was introduced to allow easy assessment of timeliness and data source and to select country reports for analysis based on a threshold quality class per variable. However, missing documentation for some countries makes it difficult to assess sources even with tiers assigned because the basis for tier selection is not provided.

3.2.3. FRA data are not experimental

Some users are accustomed to experimental data that are well controlled. The FRA data come from a variety of national sources, including district forest offices, government registries, remote sensing, national inventories and special studies. In some cases, these sources are combined to provide national statistics – statistics that are generally provided without associated measures of precision.

3.2.4. Numbers do not always add up

Ideally, forest characteristics such as primary forest, other naturally regenerated forest and planted forest should add up to the same number as total forest area. In some cases, they do and in others, they do not-in part due to missing data for one or more category or the use of more than one source for related variables.

3.2.5. FRA data are not spatially explicit

Country reports may or may not have been compiled from spatially explicit data sources, but the data submitted to the FRA are aggregated at the national level. This means that information regarding specific forest type or subnational distribution of forest resources is not reported.

3.2.6. Expectations for long-term comparison

FRA 2015 reports 25 years of forest change – which is the longest period covered by any of the FRA-related reports since 1948. While authors such as Grainger (2008 and 2014 expect data standards, variables and methods to remain constant over long periods, the reality is that they do not. New inventories and remote sensing results provide new insights into past forest area and resource information. These updates mean that aggregated values for the same reporting year are likely to change for many variables from one assessment to the next. FAO has noted that the values reported in one FRA cannot readily be compared with one another (FAO, 2010) because of the changes in definitions and new information from national monitoring and assessments. It is important to note that FRA 2015 is no different in this regard from previous assessments. Analyses of change over time are most reliably done within the 25 year coverage of FRA 2015 rather than across different FRA reports.

A summary of changes in data collection and definitions is found at http://www.fao.org/forestry/FRA2015/Historicalvariablechange.

Collectively these constraints seem exceptionally limiting – but this would be an incorrect conclusion for most purposes, particularly when examining change over a 25 year period. The FRA data point to important changes in global forest resources – not always as precisely as some users would like, but of substantial quality and usefulness.

4. Conclusions

Despite the known limitations of collecting and synthesizing information on the state, condition and trends of the world's forests there is immense value in the data collected and the analyses generated. Perhaps the best way to summarize the value of global forest resources information is to ask the question: Would forests be different today had we not known how they have changed in recent times? The answer is yes. Not knowing would have led to piecemeal attempts to focus actions by governments, donors, non-government organizations and private companies in improving forest management where they are needed most. The monetary value of actions taken as a result of global knowledge of forest resources may never be precisely known, but it is clear that humanity and forest resources are both better off as a result of the hard work of all who have contributed to understanding change in world forest resources – including those who have diligently contributed to this volume.

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