# Towards a Global Tree Assessment

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## Abstract

Tree species are of high economic, cultural and ecological value. However, increasing numbers of tree species are potentially at risk of extinction because of human activities, including forest loss and degradation, overharvesting, fire and grazing. Emerging threats include climate change and its interaction with spread of pests and diseases. The impact of such threats on the conservation status of trees is poorly understood. Here we highlight the need to conduct a comprehensive conservation assessment of the world's tree species, building on previous assessments undertaken as part of the IUCN Red List. We suggest that recent developments in plant systematics, on-line databases, remote sensing data and associated analytical tools now offer an unprecedented opportunity to conduct such a global assessment. While this represents an ambitious goal, we provide an overview of how a Global Tree Assessment could be achieved in practice, through participative, open-access approaches to data sharing and evaluation.

## Keywords

Conservation, biodiversity, forest, flora, tree, Red List, extinction risk, threat

## Introduction

Trees are of exceptionally high ecological, socio-economic and cultural importance. As the principal component of forest ecosystems, they support at least half of the Earth's terrestrial biodiversity (Millennium Ecosystem Assessment (MEA), 2005), providing habitat for 80% amphibian, 75% bird and 68% mammal species (Vié et al., 2009). Tree species richness is a major driver of richness in other species groups (Novotny et al., 2006). Forest ecosystems play a major role in the Earth's biogeochemical processes, influencing hydrological, nutrient and carbon cycles, as well as global climate (MEA, 2005). Forests contain about 50% of the world's terrestrial carbon stocks (FAO, 2010; MEA, 2005), illustrating their importance for mitigation of climate change. Trees provide a wide range of other benefits to people including production of timber, fuelwood and fibre, maintenance of water yields and quality, flood protection and prevention of soil erosion, as well as being of cultural and spiritual value (MEA, 2005; UNEP, 2009). The annual value of the ecosystem services provided by forests has been estimated at US$4.7 trillion, or 38% of the terrestrial total (Costanza et al., 1997). Some 1.6 billion people depend to some degree on trees for their livelihoods (World Bank, 2004). The total contribution of forest industries to the global economy is currently around $468 billion annually, with products valued at around US$122 billion harvested from forests each year (FAO, 2011).

The widespread loss and degradation of native forests is recognised as an environmental crisis. During 2000-2012, global forest area declined by around 2.3 million $km^2$ (Hansen et al., 2013). During the decade 2000-2010, the area of undisturbed primary forest declined by an estimated 4.2 million hectares per year (or 0.4% annually), largely because of logging and other forms of human disturbance (FAO, 2010). The conversion and degradation of forest ecosystems are major causes of biodiversity loss (MEA, 2005; UNEP, 2009; Vié et al., 2009). However, their impacts on the decline and loss of tree species are largely unknown, as their status has not been comprehensively assessed.

We believe that a complete global assessment of the conservation status of tree species is an urgent priority. Recent analyses of extinction risk in selected animal groups, namely birds, mammals and amphibians, have demonstrated the value of such a comprehensive assessment approach. As a consequence of such efforts, it is now known that 14%, 33% and 22% species of bird, amphibian and mammal species, respectively, are either threatened with extinction or are extinct (Vié et al., 2009). The status of the world’s tree species is much less well understood. An initial assessment involving around 300 experts was conducted in 1998, which evaluated 14,000 taxa of which 7886 were found to be globally threatened (Oldfield et al., 1998). As the total number of extant tree species is uncertain, it is difficult to assess the coverage of this assessment with any precision. Based on the estimate of 60,000 tree species provided by Tudge (2005), some 84% of tree species currently await assessment. As of November 2014, some 9543 assessments of tree taxa were included in the IUCN (International Union for Conservation of Nature) Red List database, representing slightly less than half of all plant species listed. Of these, 7087 submissions were contributed by Oldfield et al. (1998), which now need updating. However, a number of additional assessments have been conducted since 1998, focusing on specific geographic regions or taxonomic groups, which have not yet been added to the IUCN Red List database (Newton and Oldfield, 2008).

## Implementation of a Global Tree Assessment

Implementation of a comprehensive Global Tree Assessment (Figure 1) could usefully follow the approaches adopted in recent assessments of vertebrate groups, which have successfully mobilised global data sets and expertise. The Global Amphibian Assessment, for example, involved inputs from more than 500 specialists, who evaluated extinction risk of 5743 species over a three year period (Stuart et al., 2004). Similarly, the Global Mammal Assessment was undertaken as a collaborative effort of more than 1700 experts in 130 countries, with 5487 species assessed over five years (Schipper et al., 2008). Both of these assessments were undertaken as contributions to the IUCN Red List of Threatened Species, which is widely recognised to be the most authoritative global assessment of the conservation status of species (Mace et al., 2008). The Red List involves the application of quantitative criteria based on population size, distribution area and rate of decline, to assign species to different categories of relative extinction risk (IUCN, 2001). Information from the Red List has been widely used to inform conservation policies and legislation, as a tool for environmental monitoring and reporting, and to prioritise areas for conservation action (Mace et al., 2008; Lamoreux et al., 2003; Rodrigues et al., 2006); it has also been used at the global scale to monitor biodiversity loss (Butchart et al., 2010). While the approach can successfully be applied to tree species (Newton and Oldfield, 2008), most plant groups are grossly underrepresented in the Red List at present.

A Global Tree Assessment will represent a significantly more substantial challenge than previous vertebrate assessments, given the much larger number of species involved. The Assessment will undoubtedly require the development of an extensive global collaborative partnership, involving the coordinated effort of many institutions and individuals. However, a number of recent developments have significantly increased the feasibility of undertaking such an assessment. Initiatives such as Species 2000 / ITIS Catalogue of Life (http://www.catalogueoflife.org/), The Plant List (http://www.theplantlist.org/) and the World Checklist of Selected Plant Families provide detailed catalogues of plant species, including digital links to regional and national floras and nomenclatural databases. While these resources are not fully comprehensive and will continue to evolve in the light of ongoing taxonomic revisions, they will enable many problems of taxonomy and synonymy to be overcome, which have hindered the Red Listing of plant species in the past (Nic Lughadha et al., 2005). These resources would be used to produce the first list of all of the world's tree species, as a first stage of the proposed assessment (Figure 1).

A second key objective is the production of distribution maps of individual species, as part of the minimum supporting information required for an assessment to be published on the IUCN Red List. Development of the Global Biodiversity Information Facility (GBIF; www.gbif.org) has greatly facilitated production of species distribution maps, through its creation of an open access, globally distributed network of interoperable databases containing species location data. While it is recognised that GBIF data are incomplete and suffer from spatial bias (Beck et al., 2014, Hjarding et al. 2014), such data can be integrated with other spatial databases, such as Tropicos® (http://www.tropicos.org/), and information derived from expert knowledge. Integration of multiple sources of evidence should strengthen the overall quality of assessments. This integration can be supported by the recent development of on-line tools to support species mapping, such as the Map of Life initiative (Jetz et al., 2011), GeoCAT (Bachman et al., 2011) and the IUCN Red List Threat Mapping Application (http://research.microsoft.com/en-us/projects/threatmapping/). Further initiatives focus on use of citizen science to support species mapping, for example iNaturalist (http://www.inaturalist.org/) and iSPOT (http://www.ispotnature.org/). Such uses of web 2.0 technologies offer new approaches to collecting, mapping, and sharing geocoded data (Hudson-Smith et al., 2009), which can enable the Red List to become a more participatory process. Location data can be explored using species distribution modelling approaches to produce distribution maps of large numbers of tree species, which can inform analyses of extinction risk (Feeley and Silman, 2009; Golicher et al., 2011). In addition, high resolution maps of changes in forest extent and condition over time are increasingly becoming available, based on the analysis of satellite remote sensing imagery (Wang et al., 2005; Hansen et al., 2008, 2010, 2012; Scholes et al., 2008). Developments in web technologies now enable remote sensing data to be integrated with species distribution data, and displayed as interactive maps accessible over the internet, which can further inform the analysis of range dynamics of tree species. Such integrative approaches can enable changes in the distribution and population size of tree species to be evaluated with increasing precision (Buermann et al., 2008)

At the national scale, some countries with large numbers of tree species have made notable efforts to collect and review relevant data. For example, in 2007 the database compiled by the National Commission of Biodiversity of Mexico (CONABIO) contained 691,181 records of a total of 28,085 species of vascular plant (Soberon et al., 2007), which is available for Red List assessments. Emerging networks of forest plot data, such as RAINFOR (Malhi et al., 2002) and BIOTREE (Cayuela et al., 2012), and the national forest inventories that have been established by many countries, provide additional potential sources of information. As an illustration of the value of plot networks, ter Steege et al. (2013) recently used data from 1170 plots distributed across the entire Amazon basin to produce the first robust estimate of the total number of tree species in the region (around 16,000). Such data provide a valuable potential resource for conducting conservation assessments of tree species, which has been little used to date.

Although access to species distribution data and forest maps is improving, these are not by themselves sufficient for conducting Red List assessments, and expert knowledge is therefore likely to remain an important contributor to the process (Nic Lughadha et al., 2005). International networks of specialists have been a established to support recent assessments for Mexican and Andean cloud forest trees (Gonzalez-Espinosa et al., 2011, Tejedor Garavito et al., 2014), providing a potential model for application in other regions. For many taxa, as species distribution data are lacking, there is a need to strengthen field data collection efforts and local capacity, particularly in developing countries (Pereira & Cooper, 2006; Simons, 2011). Tools are also available to assist conducting Red List assessments with uncertain data (Newton, 2010), but these have not been widely applied to date.

We propose to implement the Global Tree Assessment using a phased approach. A series of targeted assessments would be undertaken of specific plant families with high representation of trees, such as Aquifoliaceae, Fabaceae, Fagaceae, Lauraceae, Meliaceae and Myrtaceae (totalling more than 20,000 spp.). This would build on assessments of Betulaceae and Ebenaceae that are currently in progress, led by Botanic Garden Conservation International and Missouri Botanical Garden, respectively. Themed assessments would also be undertaken of exceptionally important groups of species, such as fuelwood, ecological keystone species and forest dominants. Work on assessing timber, medicinal and crop wild relative species has recently been initiated as part of the Plants for People initiative led by IUCN. Assessments would also prioritise species at most risk from climate change, such as montane and island trees (Hawkins et al., 2008), and from other threats such as overharvesting. The ultimate objective would be to assess the conservation status of all species, using this phased approach.

It is recognised that implementation of these proposals would represent a significant advance over current assessment efforts. Since 1998, only 2456 tree species have been added to the Red List database, although many thousands of additional assessments have been made that have not yet been incorporated in the database (Newton and Oldfield, 2008; Botanic Gardens Conservation International, unpublished data). However, to mark the 50$^{th}$ anniversary of the Red List**,** IUCN has recently initiated an accelerated process to increase the number of species assessed with an aim of reaching 160,000 taxa by 2020 (IUCN, 2015). This requires a significant increase in the number of experts trained to carry out Red List assessments, as well as provision of sufficient resources, for which targeted fund raising is in progress (IUCN, 2015). A Global Tree Assessment could make a substantial contribution to this initiative, if sufficient financial resources were available.

Few data are available on the cost of undertaking Red List assessments. Martinelli et al. (2013) suggest that such costs vary widely depending on the species involved, with values ranging from US $26-440 per taxon. Similarly, IUCN (2015) suggest a figure of US $250 per taxon, which appears realistic for tree species based on recent experience (Newton and Oldfield, 2008). However, improvements in data availability, digital applications and associated tools, and adoption of the participatory assessment approach outlined here, should help the process become more cost efficient. This is illustrated by the example of the South African flora, which was recently assessed at a cost of less than US $30 per taxon. This was achieved by establishing a centralized team of ecologists to develop Red Lists, collaborating with a wide range of botanical experts, streamlining the assessment process via automation, and establishing an appropriate data management system (Raimondo et al., 2013). This approach enabled 20,456 vascular plants to be assessed within a five year period, suggesting that substantial progress towards a Global Tree Assessment could be achieved by 2020 using similar methods, if sufficient resources were made available.

**Outcomes**

Key outcomes of the assessment would include improved targeting of conservation resources specifically for tree conservation; improved design of forest conservation, restoration and management programmes; plus strengthened capacity for sustainable forest management and land planning. Re-evaluation of tree species will permit trends in extinction risk to be estimated, for example through calculation of the Red List Index (Butchart et al., 2010, Plants under pressure, 2010), providing timely and useful policy relevant information on biodiversity trends, and as a contributor to the ‘Barometer of Life’ proposed by Stuart et al. (2010).

A Global Tree Red List Assessment would support a variety of policy initiatives, including the Convention on Biological Diversity (CBD) and the UN Framework Convention on Climate Change (UNFCCC). The CBD’s Strategic Plan for Biodiversity agreed at the Tenth Meeting of the Conference of the Parties (COP10) in Nagoya, Japan, identified trends in distribution and extinction risk of species as key operational indicators. Target 2 of the Global Strategy for Plant Conservation (GSPC), a cross-cutting initiative of the CBD, refers to “an assessment of the conservation status of all known plant species, as far as possible, to guide conservation action” by 2020. A Global Tree Assessment would be an important contributor to this target. In addition, it would support implementation of the UNFCCC, which aims to tackle greenhouse gas emissions from deforestation and forest degradation through the “REDD+” programme. Recognising the potential for social and environmental risks and benefits from REDD+ (Miles & Kapos, 2008; Ghazoul et al., 2010), the UNFCCC has agreed a set of broad safeguards that countries should promote and support, specifically focusing on the conservation of natural forests and biodiversity. Improved information on the conservation status of tree species would help to focus REDD+ activities and would enhance their conservation impacts.

Red List assessments would also help prioritise tree species for conservation action. The urgency of conducting a Global Tree Assessment is highlighted by current concerns regarding large scale die-back of trees, in both temperate and tropical forests, resulting from emerging threats such as rapid spread of pests, disease and drought, and their interactions with global climate change (Allen et al., 2009; Breshears et al., 2005; Huntingford et al., 2008; Kurz et al., 2008; Raffa et al., 2008; van Mantgem et al., 2009). Concerns have also been expressed regarding ‘peak timber’ in the tropics, reflecting widespread overexploitation of timber (Shearman et al., 2012), and a global decline in large old trees, which may threaten ecosystem integrity (Lindenmayer et al., 2012). Such factors, together with the ongoing loss and degradation of forest, can potentially threaten large numbers of tree species. As illustration, of 762 species evaluated in a recent assessment of Mexican cloud forest trees, more than 60% were found to be threatened with extinction (Gonzalez-Espinosa et al., 2011). Such figures highlight the urgent need to identify threatened tree species worldwide and take immediate steps to prevent their extinction.

## Conclusions

We believe that the timing is right for launching a Global Tree Assessment. Successful achievement of this ambitious goal will require development of an unprecedented global network of botanical specialists, conservation practitioners, naturalists and plant ecologists with interests in tree conservation. We believe that recent developments in computing and web technologies will greatly facilitate the building of such an alliance, by providing tools for accessing and sharing information about the status of individual species. In this way, undertaking tree conservation assessments can become a more open, transparent and participatory process, in which contributors from anywhere in the world can become involved. Nevertheless, for this vision to be achieved, a high level of commitment will be required from the global conservation community, which will need to be sustained over a number of years. There is also a need for the provision of sufficient financial support to ensure that the assessment can be conducted successfully. We invite individuals and organisations who are concerned about the status of tree species to contribute to this process, to help conserve this vitally important element of global biodiversity.

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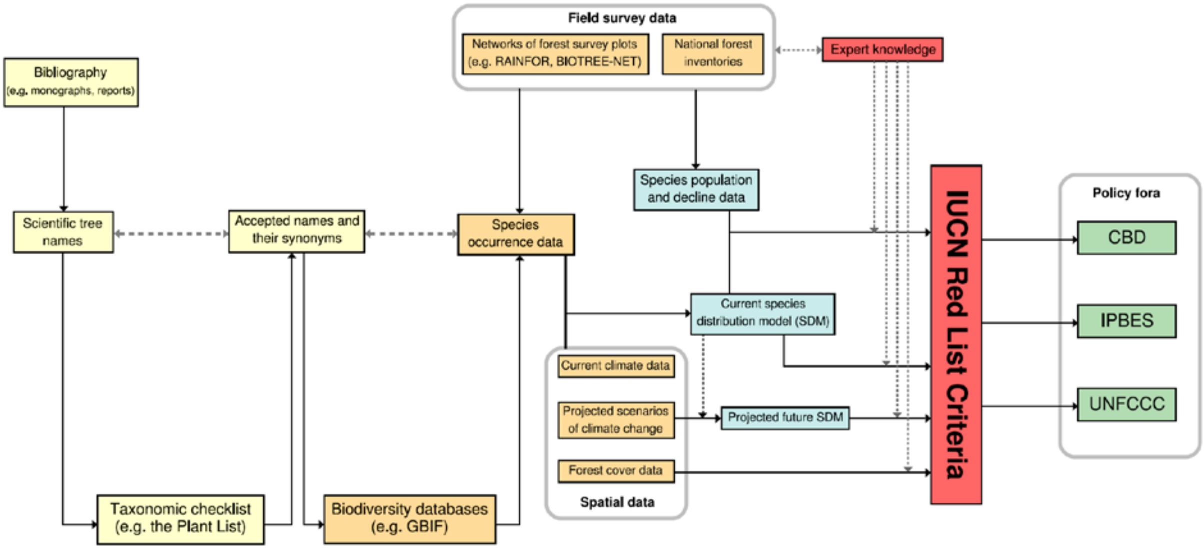
**Figure 1.** Schematic illustration of how a Global Tree Assessment could be conducted. The process will comprise four stages. (1) Taxonomic authentication, involving identification of robust nomenclature for the taxa being assessed, through reference to bibliographies, monographs, checklists and taxonomic databases (such as The Plant List; see text). (2) Distribution mapping, involving compilation of species distribution data from a range of sources, including species distribution databases (e.g. GBIF), national data centres, and networks of forest inventory and field survey plots. (3) Analysis of population trends, including compilation of abundance data from field observations, inventory data and other sources; and their integration with remote sensing data of trends in forest extent and condition, estimates of deforestation rates, etc. This integration can be supported by species distribution modelling approaches, which can be used to identify areas of potential distribution, allowing the impacts of climate change and other threats to be explored. (4) Application of Red List criteria and categories. Typically this would be undertaken by experts familiar with the taxa, supported by available maps, data and models. The engagement of such specialists throughout the process is key to its success. Formally, responsibility for quality control during the process lies with IUCN networks, such as the Global Tree Specialist Group of the IUCN Species Survival Commission. Outputs of the assessment can then inform policy implementation at national and international scales.


Field survey data
Networks of forest survey plots (e.g. RAINFOR, BIOTREE-NET)
National forest inventories
Expert knowledge
Bibliography (e.g. monographs, reports)
Species population and decline data
Policy fora
CBD
IPBES
UNFCCC
IUCN Red List Criteria
Scientific tree names
Accepted names and their synonyms
Species occurrence data
Current species distribution model (SDM)
Current climate data
Projected scenarios of climate change
Projected future SDM
Forest cover data
Spatial data
Taxonomic checklist (e.g. the Plant List)
Biodiversity databases (e.g. GBIF)