Negotiation-support toolkit for learning landscapes

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9a | Tree diversity and tree–site matching **(WhichTreeWhere?)**

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The slogan, 'The right tree in the right place for a clear function', points to the need to be specific about which trees grow where and how they can be managed to meet expectations of functions. The method described here starts with an inventory of tree presence in the landscape and local knowledge and perceptions of identity and function compared with taxonomic identity and recorded uses in existing databases. A second level of analysis in tree and site matching is understanding how tree growth and productivity depends on site conditions, which is closely linked to the question of which aspects of site conditions actually matter. A third level takes a critical look at functions in relation to landscape niches.

Introduction

Trees have both positive and negative attributes from a human perspective and the right-tree-at-the-right-place slogan suggests that specific choices out of the global spectrum of tree diversity should be combined with an appropriate concept of niches or locations where such trees are allowed to grow (if they survived and were retained from previous vegetation), allowed to settle (for spontaneously established trees) or are planted (based on availability of planting material). To further operationalize the concept we need to know 1) which trees currently grow where; 2) how well they grow at the locations where they grow; 3) what direct and indirect functions they have associated with their properties; and 4) how important tree diversity is at multiple scales of management.

Tree diversity depends on the scale of consideration. At global scale there are approximately 100 000 species of trees, which is one quarter of all plants, spread over about 250 plant families[1]. Woody perennials occur in six of 11 divisions of plants: *Angiospermae* (including monocots, eudicots), *Magnoliophyta*, *Gnetophyta*, *Pinophyta* (=Coniferae), *Cycadophyta*, *Pteridophyta*). In many genera there are trees and non-trees. This implies that either the genetic base of being a woody perennial has been reinvented many times or that such genes can be easily switched off and on during evolutionary change.

On the other end of the scale, we can consider a single tree species with its intraspecific genetic diversity and an often complex network of relationships with relatives that can be teased apart with genetic markers. At scales in between, we consider the tree diversity of a plot, a farm, a landscape transsect, watershed or ecoregional zone. With respect to human use, some value chains demand specific properties, defined below the species level as in tree crops with distinct cultivars, others use broad 'trade names' that can refer to multiple species. The simplest distinction of timber (floaters

[1] In the discussions around the definition of 'forest', the concept of 'tree' is important because forests tend to be defined relative to the presence of trees; and if an oil palm is a tree, conversion of forests to oil-palm plantations is not 'deforestation'.

versus sinkers) not only indicates consequences for the mode of downstream transport but also the wood density and correlates of strength and durability.

At plot level, (alpha) tree diversity comes in four shades of grey: no trees; monoculture of a single species; simple mixed system with limited (usually 2–5) species diversity; and complex mixed systems with higher diversity. The beta diversity describes the diversity across a category of plots: even for systems that are 'simple mixed' systems at plot level, the total diversity can be high if the companion trees of the dominant component are varied from plot to plot. On the high end of diversity, where the pre-human diversity of the natural landscape is the point of reference, we can quantify and understand the characteristics of the 'diversity deficit'[2]. At the gamma diversity scale of a landscape we can consider which groups of species from the original flora are underrepresented in the human-dominated landscape and which ones are overrepresented. Research so far suggests that the dispersal mode of tree seeds, as well as the direct use value for humans, are both involved, interacting with human management styles and local ecological knowledge (Joshi et al 2003, Tata et al 2008). Databases with such tree properties need to be combined with survey data.

In the background of the 'forest transition curve', a 'tree diversity transition' is taking place (Ordonez et al 2014, Figure 9a.1): depending on the part of the tree life cycle considered (seedbank, seedlings, saplings, poles or reproductive trees), we can now expect multiple lines for the loss of tree diversity during forest conversion, while the recovery phase of agroforestation or reforestation involves a gradual increase of the diversity of planted trees. Agroforestry systems differ in tree origin, although systematic data on this aspect are not yet available.

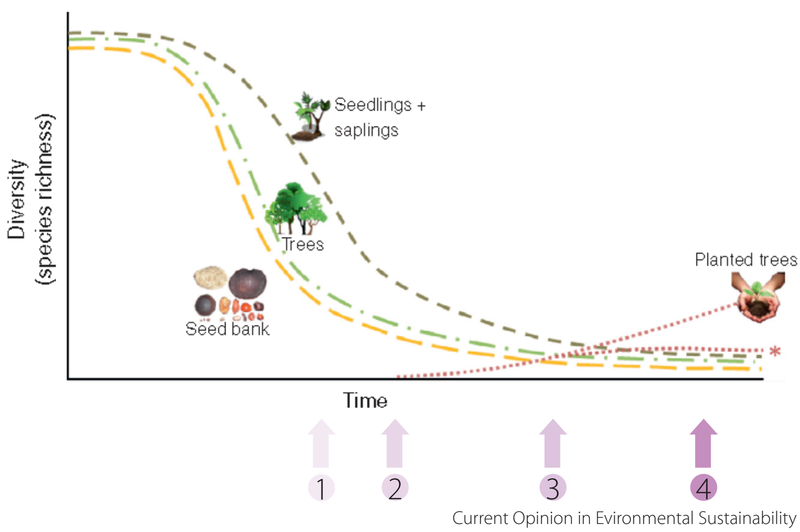


Figure 9a.1. Tree diversity transition curve

Source: Ordonnez et al 2014

[2] Villamor et al (2011) considered diversity deficits in three domains: 1) in the real world where actual diversity is less than a potential state that is deemed desirable (hence we worry about loss of biodiversity and cultural diversity); 2) in representation and modelling of the real world (where 'residual variance' may represent a diversity deficit of the model); and 3) in our recognition of the driving forces that are used to construct a model (a diversity deficit due to oversimplification). Diversity in the real world is lost when it disappears from the knowledge that is being shared.

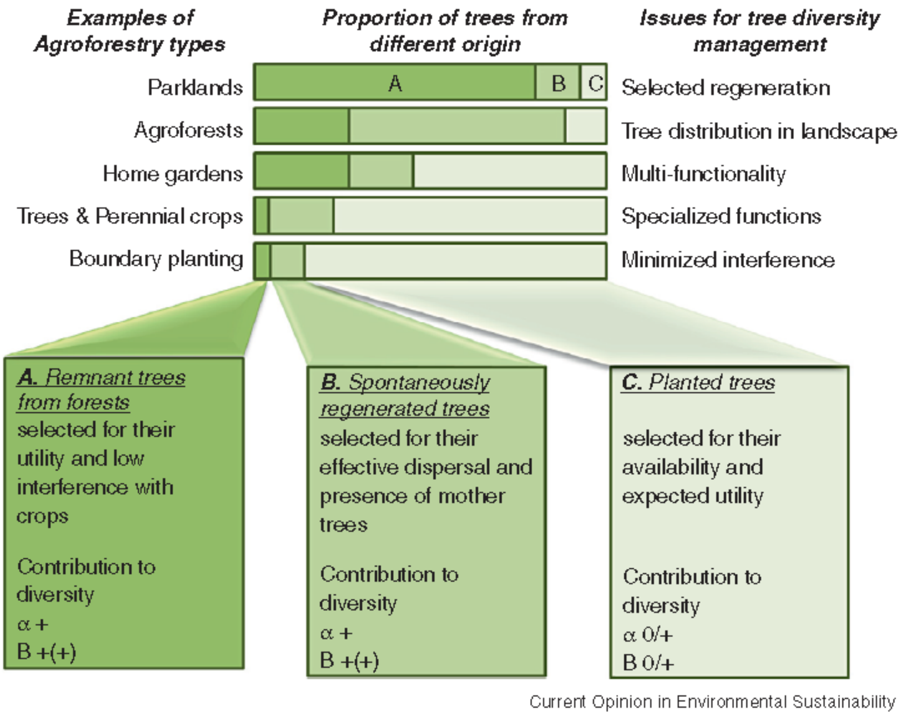


Figure 9a.2. Tree portfolios of agroforestry systems by origin of the trees

Source: Ordonnez et al 2014

Objectives

The WhichTreeWhere? tool systematically collects data of trees found on farms and in the landscape, allowing an analysis of tree portfolios with respect to functional properties as well as tree–site matching with respect to expected tree growth rates under current and future climate conditions.

Steps

1. Data collection of field occurrence of trees at plot, farm or landscape transect scale
   a. The choice of sampling scale (plot, farm or landscape transect) will often depend on the opportunities for synergy with other research, for example, economics (for which plot and farm are relevant), carbon stocks (plot or landscape scale) or watershed functions (specific landscape niches, such as riparian zones, slopes sensitive to landslides)
   b. Measurement protocols normally use tree stem diameter at breast height (1.3 m above the ground; for special cases see Hairiah et al 2011) as the basis for allometrics, accompanied by tree height for trees in more open landscape conditions (in closed stands it is difficult to measure and adds little information to allometrics); this is to be linked to tree identity in local taxonomy (linked to use value) and botanical taxonomy; the latter may require collection of specimens for herbarium comparisons

c. Assistance of local informants may be needed to record the origin of the tree as 1) retained from preceding vegetation; 2) spontaneously established; or 3) planted. An intermediate category is 'farmer-managed natural regeneration', which is mostly in category 2. Finer distinctions in 'planted' (3) can be: 3a) directly seeded; 3b) transplanted wildings; 3c) transplanted from nursery; 3d) grafted in nursery; 3e) grafted in situ on planted rootstock; 3f) grafted on spontaneously established trees. And further categories as locally appropriate

2 Linking local and botanical tree taxonomy to use values and other knowledge

a. Local tree taxonomy tends to differ substantially from the botanical, as it is generally linked to use value. For fruit trees this may, for example, mean that varieties within a single species are differentiated by name; for timber species, terms such as 'medang' or 'meranti' can cover a wide range of botanical species

b. Methods to explore local knowledge of trees and their properties are provided with AKT5

3 Linking tree data to functional attributes in dedicated databases

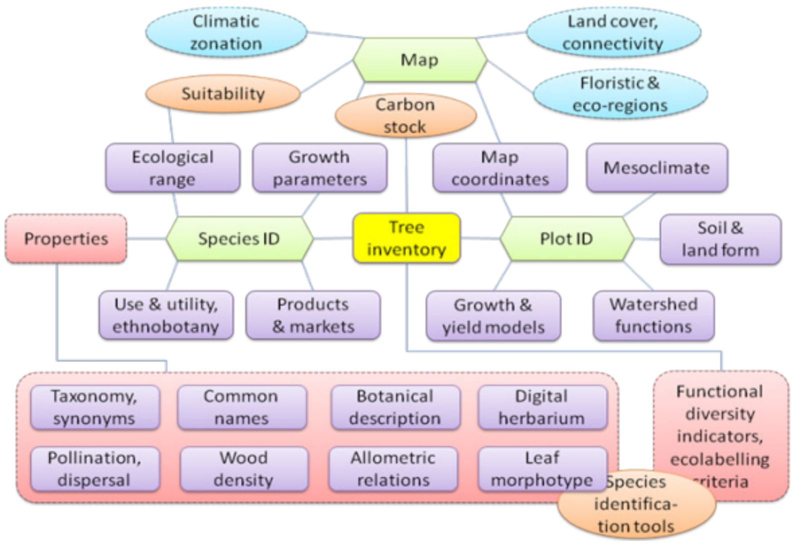


Figure 9a.3. Module diagram of Tree FUNATIC database

4 Analyzing tree growth in relation to site properties and climate

a. If tree or site-level properties of soil, climate and management are recorded, as well as age of the tree, the predictive power of such variables[3] in accounting for tree growth rates can be tested (Santos-Martin et al 2010)

b. Using existing spatial databases, the climatic conditions where the trees occur and basic soil and site properties can be used to map 'climatic suitability' for trees, especially for those with high use value. In combination with climate-change predictions, this may assist anticipating the growth conditions under which a tree will mature in the choice of what is currently planted.

[3] For example, landscape position, soil texture, organic matter, soil chemical and soil biological properties in order of increasing data cost; interacting with farmers' characteristics and management styles

A number of databases are now available that can assist with such analyses. The Agroforestry Species Switchboard (www.worldagroforestry.org/products/switchboard/index.php) provides easy access. It includes an option of searching for a genus or species by directly typing the name of the URL (hyperlink) in the web browser: http://www.worldagroforestry.org/products/switchboard/index.php/name_like/ .

Agroforestree database

The Agroforestree database is a species' reference and selection guide for agroforestry trees. In the context of the database, agroforestry trees are those that are deliberately grown or kept in integrated land-use systems and are often managed for more than one output. They are expected to make a significant economic or ecological impact, or both.

The main objective of the database is to provide detailed information on a number of species to field workers and researchers who are engaged in activities involving trees suitable for agroforestry systems and technologies. It is designed to help them make rational decisions regarding the choice of candidate species for defined purposes. Information for each species covers identity, ecology and distribution, propagation and management, functional uses, pests and diseases and a bibliography. To date, more than 500 species have been included. The specific aims of the database are to

1. enable quick and efficient access to a consolidated pool of information on tree species that can assume useful production or service functions, or both;
2. provide a tool that will assist with the selection of species for use in agroforestry and related research, using factors that are relevant to the chosen agroforestry technologies;
3. help researchers assess potential agroforestry trees for uses other than those commonly known, such as timber; and
4. provide indicators for the economic assessment of species through yield information on tree products.

Download from http://www.worldagroforestry.org/sea/Products/AFDbases/AF/index.asp.

Wood density database

The wood density database records the dry weight per unit volume of wood for particular species. It can be used in allometric equations that estimate tree biomass and carbon stocks from stem diameter values (for example, W = 0.11 r D2+c , Ketterings et al 2001. Reducing uncertainty in the use of allometric biomass equations for predicting above-ground tree biomass in mixed secondary forests. *Forest Ecology and Management* 146:199–209) and indicate the use value (higher density wood tends to burn slower and is thus more useful as firewood or as source of charcoal, it also correlates with strength, although there are better parameters for strength per se).

Wood density varies with tree species, growth conditions and part of the tree measured. The main stem generally has a higher wood density than the branches, while fast growth is generally related to relatively low wood density. For most species, the literature thus gives a range with low, medium and high values. In this database we have collected quantitative information from a number of publicly available sources. As you will note, there is no standardization of the moisture content of the ('air dry') wood in the densities reported and some conversions may be needed. For questions and comments please contact s.rahayu@cgiar.org.

Download from http://worldagroforestrycentre.org/regions/southeast_asia/resources/wood-density-database.

Tree diversity analysis

A manual and software for common statistical methods for ecological and biodiversity studies

Effective data analysis requires familiarity with basic concepts and an ability to use a set of standard tools, as well as creativity and imagination. Tree diversity analysis provides a solid practical foundation for training in statistical methods for ecological and biodiversity studies.

This manual arose from training researchers to analyse tree diversity data collected on African farms, yet the statistical methods can be used for a wider range of organisms, for different hierarchical levels of biodiversity and for a variety of environments, making it an invaluable tool for scientists and students alike.

Focusing on the analysis of species survey data, *Tree diversity analysis* provides a comprehensive review of the methods that are most often used in recent diversity and community ecology literature including:

- species accumulation curves for site-based and individual-based species accumulation, including a new technique for exact calculation of site-based species accumulation;
- description of appropriate methods for investigating differences in diversity and evenness, such as Rényi diversity profiles, including methods of rarefaction to the same sample size for different subsets of the data;
- modern regression methods of generalized linear models and generalized additive models that are often appropriate for investigating patterns of species occurrence and species counts; and
- methods of ordination for investigating community structure and the influence of environmental characteristics, including recent methods such as distance-based redundancy analysis and constrained analysis of principal coordinates.

The BiodiversityR software was initially developed for the R 2.1.1 statistical environment. Please check for changes in installation procedures and some new options for data preparation in the document provided below.

Download from http://worldagroforestrycentre.org/resources/databases/tree-diversity-analysis.

Molecular markers for tropical trees: statistical analysis of dominant data

In the last decade, there has been an enormous increase worldwide in the use of molecular marker methods to assess genetic variation in trees. These approaches can provide significant insights into the defining features of different taxa and this information may be used to define appropriate management strategies for species.

However, a survey of the literature indicates that the implementation of practical, more optimal management strategies based on results from molecular marker research is very limited to date for tropical trees. In order to explore why this is the case, the World Agroforestry Centre undertook a survey of molecular laboratories in low-income countries in the tropics. The survey looked at the kinds of molecular marker studies that were being carried out on tree species and the problems faced by scientists in this research.

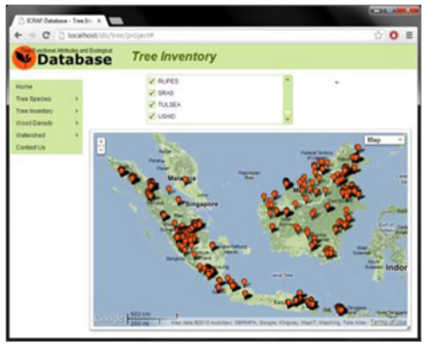
One of the constraints that the survey identified for the proper application of molecular markers is the effective handling and analysis of data sets once they have been generated. This guide has been designed to address this need for data obtained using dominant marker techniques. It has been created especially for students (MSc, PhD) and other researchers in developing countries who find themselves isolated from their peers and—when faced with an apparently bewildering array of options—find it difficult to settle on appropriate methods for analysis.

Most benefit will be obtained from this guide if it is used together with the companion volume on practical protocols for molecular methods (ICRAF Technical Manual no. 9) and so we recommend that scientists read both.

Download from http://worldagroforestrycentre.org/resources/databases/molecular-markers-for-tropical-trees.

Tree functional attributes and ecological database (Tree FUNATIC)

Tree FUNATIC is a web-based database that both stores and gives information about the attributes and ecological information of a variety of tree species, including taxonomy, geographic distribution, ecological range, functions and wood density. The database also stores tree entity information from observations, such as stem diameter, height and crown dimensions, as well as habitat information, including that geographic information on soils and climate.
Tree FUNATIC is a web application that can be accessed anywhere and anytime within internet coverage. The Tree FUNATIC application is made with a simple interface using the latest technology to enable easy access for users to get the information they need. Most of the database can be accessed by the public; some information can be accessed only through membership.



The Tree FUNATIC Database is accessible at http://db.worldagroforestry.org/.

- Tree site distribution based on climate, soil and elevation range of each species.
- Uses and function of each species.
- Wood-density information extracted from species, genus, family, common name.
- Carbon-stock information at plot level in various locations, especially Indonesia.
- Species allometry to estimate tree biomass.
- Tree market, supplier and location information.
- Tree-species identification based on morphotype and herbarium database.
- Watershed along with its climate information.

Tree FUNATIC Database is a relational database using MySQL as its server. Members can access the MySQL to do direct queries using the SQL language code. Currently, Tree FUNATIC has 452 allometry data per species to estimate biomass in various locations gathered from various literature sources. The database is still under active development.

The landscape scale is a meeting point for bottom–up local initiatives to secure and improve livelihoods from agriculture, agroforestry and forest management, and top–down concerns and incentives related to planetary boundaries to human resource use.

Sustainable development goals require a substantial change of direction from the past when economic growth was usually accompanied by environmental degradation, with the increase of atmospheric greenhouse gasses as a symptom, but also as an issue that needs to be managed as such.

In landscapes around the world, active learning takes place with experiments that involve changes in technology, farming systems, value chains, livelihoods' strategies and institutions. An overarching hypothesis that is being tested is:

> Investment in institutionalising rewards for the environmental services that are provided by multifunctional landscapes with trees is a cost-effective and fair way to reduce vulnerability of rural livelihoods to climate change and to avoid larger costs of specific 'adaptation' while enhancing carbon stocks in the landscape.

Such changes can't come overnight. A complex process of negotiations among stakeholders is usually needed. The divergence of knowledge and claims to knowledge is a major hurdle in the negotiation process.

The collection of tools—methods, approaches and computer models—presented here was shaped by over a decade of involvement in supporting such negotiations in landscapes where a lot is at stake. The tools are meant to support further learning and effectively sharing experience towards smarter landscape management.

World Agroforestry Centre
ASB Partnership for the Tropical Forest Margins
AARD
Federal Ministry for Economic Cooperation and Development
Norad
IFAD Enabling poor rural people to overcome poverty
CGIAR Research Program on Forests, Trees, and Agroforestry