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A gap in the woods: Wood density knowledge as impediment to develop sustainable use in Atlantic Forest

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ABSTRACT

To achieve sustainable forest management, forests scientists and managers require ecological data such as tree size, growth rate, wood density, species abundance and forest structure. Lack of specific knowledge on these features may compromise the sustainable use of natural resources. Considering tree species, wood density may be considered as the most integrative trait, usually associated with two major growth syndromes, setting apart pioneer and climax species, and driving potential uses of wood. Therefore, we chose this trait as an indicator for the scientific knowledge level about Atlantic Forest tree species, under the assumption that it is an impediment for their management and conservation. We use Logistic Regression models to test if wood density is less known (i) due to species restricted distribution, (ii) due to species abundance, and/or (iii) species unknown use value. As an alternative to fill this gap we test if it is possible to predict wood density from related species using a null model. We could not find any wood density record for 73.4% of the studied species. We also detected a consistent spatial bias with collection data closer to research centers than expected by chance. Also, larger distribution area and more recognized use value of a given species is associated with a higher chance of having wood density records in the literature. It was possible to use available knowledge about wood density of related species in a genus for 15 of the 57 studied genera. Our results show that, besides the lack of information on wood density, there is uncertainty about the capability of the existent data to express trait variability for Atlantic Forest trees. Therefore, to ensure adequate wood supply and species conservation it is imperative to fill knowledge gaps on wood density in the Atlantic Forest.

1. Introduction

Forest management is a science-based activity that relies on the best knowledge of structure and function of forest ecosystems to design optimal and sustainable management practices. Thus, information about tree-abundance (Antos et al., 2016), forest structure (Ali and Mattsson, 2018; da Cunha et al., 2016; Pretzsch et al., 2008), tree diameter and height distribution (da Cunha et al., 2016; Pereira et al., 2002; Pretzsch et al., 2008), only to name a few, directly affect the choice and effectivity of management practices. Under this perspective, it is fair to assume that the lack of detailed studies on these subjects, especially in tropical forests, may constrain technological development and compromise sustainable management of natural resources (Balmford et al., 2003). Specifically, the lack of knowledge about tree ecological traits, recently named Raunkiæran shortfall (Hortal et al., 2015), is a serious impediment to our understanding of the ecological processes that organize tree communities (Burton et al., 2009; Glatthorn et al., 2017; Jeffries et al., 2010; Kariuki et al., 2006) and affect its management.

The increase in knowledge about ecological traits is relevant to understand the ecological processes involved in the growth of tropical trees, for instance, wood characteristics have longed been recognized as key factors to determine native tree growth (Cornwell et al., 2009; Kraft et al., 2010; Shimamoto et al., 2016). Pioneer species often have rapid growth, low-density wood and large numbers of small heliophilous seeds, while climax species often have slow growth, high-density wood, and few large ombrophilous seeds (Martins Maciel et al., 2003; Swaine and Whitmore, 1988). These two major set of characteristics are the extremes of an evident continuum of possibilities. Notwithstanding, wood density remains as the best trait to distinguish between these set of characteristics and to determine potential uses (Trugilho et al., 1990). Thus, the lack of information regarding this variable directly affects our understanding about the dynamics of tropical forests and prevents further discussion regarding the use of native plants. In this

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study we chose to use this trait as an indicator of our current knowledge level about Atlantic Forest wood species.

Wood is a heterogeneous, porous, hygroscopic and anisotropic organic material, which is a common resource for various purposes (Filková et al., 2015; Haneca et al., 2005). The main uses for the wood of a given species can be predicted by their density, since this measure is correlated with mechanical properties such as flexion, compression and support against gravity (Faggiano and Marzo, 2015; Hacke et al., 2001). These properties are expected to vary among species and with the environmental conditions (Latorraca and Albuquerque, 2000); however, studies have shown that wood density is strongly conserved in the phylogeny (Chave et al., 2006; Swenson and Enquist, 2007). Therefore, the phylogenetic structure could be used to infer about possible uses of a given species with no wood density information (Swenson, 2014).

The timber industry in Brazil is based mainly on the monoculture of exotic species and is experiencing an increase in the demand for wood products. This scenario resulted in an expansion of planted forest areas. Between 2011 and 2012, the area occupied by forest monocultures was estimated at 7.2 million hectares (Serviço Florestal Brasileiro, 2013); in 2016 this number rose to 10 million hectares (IBGE, 2016). Brazilian forestry area is 75% occupied by *Eucalyptus* spp., 21% by *Pinus* spp. and 4% by *Acacia mearnsii*, *Tectona grandis*, *Hevea* spp., *Schizolobium parahyba* or *Araucaria angustifolia* (IBGE, 2015). From those, only the last three species are native to Brazil. Despite contributing to natural resources conservation (Felton et al., 2016), exotic species introduction poses a risk to native biodiversity due to direct habitat loss and fragmentation, increase of potential invasions and changes in ecosystem functioning (Dodet and Collet, 2012; Felton et al., 2013; Woziwoda et al., 2014). An alternative to exotic species forestry is the production of wood from native species, which is constrained by our current knowledge level about these plants.

The colonization of Brazil originated in the Atlantic Forest biome. The forest provided resources for early stages of economic growth, but was subsequently fragmented by railroads and highways, and converted into cities (Morellato and Haddad, 2000). This conversion reduced the area of the Atlantic Forest biome to approximately 8.5% of its original 1.3 million km^2, threatening at least 1500 species of its native flora (Martinelli and Moraes, 2013) and 598 species of its native fauna, 428 of which are endemic (ICMBio, 2016). Our current knowledge of the species of this biome is biased towards species that are able to develop closer to converted areas and big cities where the main research centers are located. This gap pattern has already been found in a number of other papers (De Marco and Vianna, 2005; Mair and Ruete, 2016). In addition, this region has the largest research institutes and cities, maintaining a sizeable amount of knowledge about Brazilian tree species. However, the occupation and development of this area is not homogeneous, so we also expect to find consistent spatial bias within the biome.

Rarity may be one possible explanation for the variation in the degree of biological knowledge among species. Both range size and perceived local abundance were previously used as ecological surrogates for rarity (Gaston, 1994). For wood tree species, it is possible that its perceived economic value affects the variation of the research intensity among species. Here, we evaluate these hypotheses considering the knowledge about wood density among Atlantic Forest tree species. Specifically, we test the predictions that species that are less known are so because: (1) they have a restricted distribution; (2) they are not abundant; and/or (3) they have unknown use value. In addition, we present an extensive evaluation of the distribution of available wood density information among Atlantic Forest native tree species. Finally, we also aimed to fill this knowledge gap by evaluating the hypothesis that related species have more similar wood density than expected by chance.

2. Material and methods

2.1. Selection of species and assembly of databases

2.1.1. Taxonomic database

We evaluated species included in the Brazilian Flora 2020, a database compiled by Botanical Garden of Rio de Janeiro – BGRJ (Zappi et al., 2015), that meets the following criteria: angiosperms and gymnosperms, arboreal, terrestrial and native from Atlantic Forest, excluding Cactaceae and Poaceae (subfamily Bambusoideae). Our search resulted in a taxonomic database with 3143 species, of which 3140 were angiosperms and three gymnosperms. The angiosperms are distributed among 28 orders, 105 families and 523 genera, while gymnosperms are distributed in two families and two genera. Access to the BGRJ database was made on February 2016.

2.1.2. Wood density database

To build a wood density database, we performed searches with the terms “wood density” or ”wood specific gravity” combined with “Atlantic Forest“ or “Brazilian Atlantic Forest”, in Portuguese and English, in the databases of Web of Science and Google Scholar between May 2015 and August 2016. We also consulted books on the subject (Carvalho, 2014, 2010, 2008, 2006, 2003; Wittmann, 2010). Our searches returned 159 bibliographic references. We also consulted two electronic databases: (i) Global Wood Density Database (http://datadryad.org/handle/10255/dryad.235) (Chave et al., 2009; Zanne et al., 2009) and (ii) database of Empresa Brasileira de Pesquisa Agropecuária – Embrapa Florestas (http://www.cnpf.embrapa.br/pesquisa/efb/). Those databases are expected to include most of the published records, but they also maintain not-published results of ongoing studies. All information retrieved from those sources were carefully evaluated and only included in our analysis if they meet the following criteria: (i) the presence of at least one density value (basic, apparent or specific) or wood specific gravity for one or more species that compose the taxonomic database and (ii) the work was carried out within the biome distribution. We used the spatial limits of Atlantic Forest biome as defined by Brazilian Institute of Geography and Statistics (IBGE – www.ibge.gov.br). As a result, we obtained a wood density database composed of 20 scientific articles, 37 technical documents, six works published as the result of events, six books, 21 academic not published studies, such as monographs, dissertations and theses, and two databases in spreadsheet format. Pooled together this information refer to 813 species of the taxonomic database.

2.1.3. Species population density database

To build the population density database for Atlantic Forest tree species we searched the terms “'composition' AND 'floristic' AND 'Atlantic Forest'”, “'phytosociology' AND 'Atlantic Forest'”, “'composition' AND 'floristic' AND 'Atlantic Forest' AND 'phytosociol*'” and “Atlantic Forest phytosociology”, in Portuguese and English, in the databases of Web of Science and Scopus and in the online platform of the journal Biota Neotropica between March and June 2016. Our searches returned 126 scientific articles. All information retrieved was evaluated and only retained for our analysis those that met the following two criteria: (i) the phytosociological inventory was carried out within the Atlantic Forest biome and (ii) the methodology used allows the calculation of species density (number of individuals/m^2), considering the species that make up the taxonomic database. The 26 articles resulting from this evaluation provided density data for 497 species of the taxonomic database.

2.1.4. Species distribution database

The estimation of the species distribution area is directly linked with the number of occurrence points collected and made available. By itself, this number can be used as indicator of the existing knowledge level regarding a species. Collecting information on occurrence points is a