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WoodProperty.tw: a wood property database for tree and bamboo species in Taiwan

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ABSTRACT: Wood and bamboo represent the biomass accumulated over the life history of trees and bamboos, playing critical roles in both biotic and abiotic processes within ecosystems. These materials also serve as vital renewable resources for humanity, contributing to the sustainable utilization of natural resources and underpinning the advancement of human civilization. A thorough understanding of the properties of wood and bamboo across different species is essential for the sustainable management of forest ecosystems and the efficient use of these resources. Previously, research outcome on wood and bamboo properties in Taiwan has been fragmented, with findings scattered across diverse printed literature, hindering access and utilization. This study presents a systematic review of scientific publications from Taiwan, extracting wood property data from various tree and bamboo species and integrating this information into a comprehensive, computerized database. The resulting database, "WoodProperty.tw", compiles data extracted from 156 documents published between 1947 and 2018, encompassing 5,762 records and 236 data fields of wood property data for 607 species in Taiwan. WoodProperty.tw features standardized and clearly defined data fields, traceable source literature, and unified species taxonomic information. It is released under a Creative Commons Attribution 4.0 License (CC BY 4.0) and is publicly accessible for download, use, adaptation, and distribution.

KEY WORDS: bamboo, literature-based, open access, relational database, tree, wood property.

INTRODUCTION

Wood and bamboo culms (hereafter collectively referred to as wood) are core products of tree and bamboo growth, forming the body structure and growth patterns of these woody plants, and representing the biomass accumulated over their life histories (Chave *et al.*, 2009; Akinlabi *et al.*, 2017). This natural resource, primarily composed of carbohydrates, is the most critical natural organic matter in terrestrial ecosystems, mediating carbon cycling and resource allocation within ecosystems (Barnes *et al.*, 1998; Anderson-Teixeira *et al.*, 2021). Beyond its pivotal role in abiotic processes, wood also acts as an essential material, substrate, and structural element of ecological habitats, supporting vast biodiversity (Sandström *et al.*, 2019; Ampoorter *et al.*, 2020). Even for the plants growing wood *per se*, tree species in a forest commonly exhibit different life history performances and ecological functions associated with the variation in wood properties (Chave *et al.*, 2009). For instance, species with low wood specific gravity (*i.e.*, low wood density) frequently perform as pioneer species in forest communities, characterized by faster growth but shorter lifespans, whereas species with high wood specific gravity typically establish later in succession, growing slowly but living longer (Chave *et al.*, 2009; Rüger *et al.*, 2018). Species with greater wood strength, as reflected in the mechanical properties of their wood, are more capable of withstanding wind disturbances such as strong gusts or typhoons, thereby exhibiting greater resistance (Van Gelder *et al.*, 2006; Chave *et al.*, 2009). Therefore, understanding the wood properties of different tree species is instrumental in comprehending and predicting the dynamics and functioning of forest ecosystems and the biological communities living within them. This knowledge is of significant value for the growth, management, conservation, and assessment of forest resources.

Wood is also a vital renewable resource for the sustainable utilization of natural resources by humanity (Forest Products Laboratory, 2010). Its widespread applications encompass construction and craft materials, paper production, essential oil extraction, fuel use, and biomedical material development (Niemz *et al.*, 2023). As a fundamental resource, wood has played a pivotal role in the advancement of human civilization. Application of wood for each intended use requires specific wood properties, necessitating the selection of appropriate tree and bamboo species (hereafter collectively referred to as tree species) (Forest Products Laboratory, 2010). For instance, construction works demand wood with suitable physical, mechanical, and processing properties. By contrast, the utilization of wood fibers and essential oils requires a comprehensive understanding of the chemical properties of different wood species (Niemz *et al.*, 2023). In summary, wood possesses significant ecological, environmental, industrial, and livelihood importance for the natural environment and human civilization. Therefore, a thorough knowledge of the wood properties of various tree species is key to efficiently utilizing wood resources and establishing sustainable forest management practices.

Wood properties vary substantially across tree species. In Taiwan, there are over one thousand native tree species (The Editorial Committee of the Flora of Taiwan, 1993–2003) and hundreds of introduced species (Liu *et al.*, 1994). Given this rich diversity of tree species, measuring and compiling data on wood properties from various species constitutes a foundational knowledge resource. Previously, long-standing research results on wood properties in Taiwan have been primarily presented in the form of wood atlases (*i.e.*, illustrated guides to wood identification, whether printed or online) or scattered across various academic publications and gray literature. Until recently, Chao *et al.* (2022) established a wood-related database tailored for carbon stock estimation. However, the collection scope of Chao *et al.*'s database is limited to two wood properties: wood density and carbon content. Consequently, a comprehensive, computerized, and publicly accessible database of wood properties has yet to be developed. This ongoing data deficiency may hinder the advancement of research and practices in forest-related sectors.

This study aims to conduct a systematic literature review of scientific publications to extract wood property data for the diverse species in Taiwan. The extracted information is subsequently digitized and integrated into a computerized database named "WoodProperty.tw", which encompasses a comprehensive collection of wood property data for tree species in Taiwan. WoodProperty.tw features standardized and clearly defined data fields, traceable source literature, and unified species taxonomic information. It is publicly accessible for download, use, adaptation, and distribution.

MATERIALS AND METHODS

Literature search and review

To identify relevant literature, a systematic search was conducted using the *Taiwan Periodical Literature Database* hosted by the National Central Library (https://tpl.ncl.edu.tw/NclService/). Additionally, the physical collections and digital resources from forestry libraries in Taiwan were also searched. The search focused on major forestry academic journals and serial publications published in Taiwan since the end of World War II (1946-2023) (see Table S1 in the Appendix). The resulting bibliographic information was carefully evaluated to identify research literature specifically focused on the fundamental wood properties of tree species. Additionally, the literature search was extended to include wood atlases, wood science textbooks, technical reports, research bulletins episodically published by forestry departments, and relevant journal articles published in international journals. Given the lack of a bibliographic database for these types of documents, a general literature search approach was employed for collection.

As for master's and doctoral dissertations, this study did not conduct a comprehensive search. Only those dissertations that presented systematic investigations of wood properties from various tree species were surveyed (most of which have subsequently been published as journal articles and integrated into this study).

Data extracting and digitizing

This study focused on collecting wood property data of native tree species and introduced species of practical forestry application in Taiwan. Commercial timber species that were imported from other countries and generally not cultivated in Taiwan were excluded. Additionally, this study solely focused on the research findings derived from solid wood (real wood). The wood properties of engineered wood products were not included. The data collection was concentrated on quantitative wood properties, whereas qualitative descriptions, typically associated with wood morphological features, were selectively included. Data that lacked clear definitions in the literature or did not align with the standard scope of wood science were excluded. To minimize data redundancy in the database, if a wood property within the literature was cited from other references, only data from the original publication was included. Moreover, to effectively collect wood property data from systematic measurement studies, only literature reporting data for a minimum of three species was included.

Following these collection criteria, the relevant wood property information of each screened literature was input into a wood property data table. To facilitate the comparison between the data table and literature, the wood property data was input exactly following the table format presented in the source literature. This data extracting and digitizing workflow created a computer database oriented to conveniently manipulate, analyze, and share wood property data. A data table of source literature was also established to provide the bibliographic information of the included literature.

Collating and unifying taxonomic information

The database compiled literature spanning a wide temporal range. As a result, the same tree species was often recorded under different scientific names or local vernacular names used in various publications from Taiwan. Moreover, some literature has reexamined the classification of tree species based on wood morphological characteristics and proposed new taxonomic treatments. Consequently, the taxonomic information directly extracted from these sources lacked a unified taxonomic standard and required integration.

The integration of species taxonomic information was conducted in two steps. The first step was to verify species identity. This study comprehensively referenced prominent botanical and dendrological literature in

Taiwan (Liu, 1960–1962; Li, 1963; The Editorial Committee of the Flora of Taiwan, 1975–1980, 1993–2003; Liu *et al.*, 1994; Yang and Liu, 2002), as well as the online database *Plants of Taiwan* (Institute of Ecology and Evolutionary Biology of National Taiwan University, 2024), to identify the corresponding tree species for each scientific or vernacular name recorded in the literature.

After confirming species identities, the second step was to standardize the nomenclatural information within the database. The *Catalogue of Life in Taiwan* database (TaiCOL) was adopted as the authoritative reference for taxonomic nomenclature (Chung and Shao, 2022). A corresponding data table of species taxonomic information was created by matching to the TaiCOL information. The original scientific and vernacular names used in the source literature were preserved in data fields in the wood property data table for user reference. Following the integration process, nine tree species were found to be absent from the TaiCOL database. These species were either from certain non-native introductions and cultivars not included in TaiCOL (four species), or belonging to newly described taxa in the source literature (five species). For the former, the taxonomic information from the checklist of the vascular plants of Taiwan in The Editorial Committee of the Flora of Taiwan (1975–1980) was adopted. For the latter, the taxonomic treatment and information reported in the source literature was retained. The corresponding notes for these situations were added to a "taxonRemarks" field in the data table to provide additional information. Moreover, the data fields related to taxonomical information were named in compliance with the Darwin Core terms (Darwin Core Maintenance Group, 2021). For those taxonomic fields not matched in the Darwin Core terms, the same naming vocabularies were also adopted.

Data integration

After digitizing and organizing the data, three primary data tables were created: a wood property data table, a source literature data table, and a species information data table. These data tables were integrated into a relational database structure. Within this database, each record of wood properties was linked to its source literature, and all tree species were recorded according to a standardized taxonomic information source.

Furthermore, this study rectified and unified the names, definitions, and units (using the metric system) of wood properties used in various literature sources. This standardization ensured data consistency in each data field. Accordingly, the study constructed the metadata for the three data tables in the database. The metadata fields were designed in both Chinese (traditional) and English to provide language support for forest practitioners accustomed to using Chinese (Tables S2–S4).

The completed database and associated metadata, named "WoodProperty.tw", have been deposited in the Zenodo repository (Su, 2025) and are publicly accessible under a Creative Commons Attribution 4.0 License (CC BY 4.0). A script file of SQL-92 Data Definition Language (DDL) codes, designed to construct the relational database structure within a database management system, was also provided in the repository.

RESULTS AND DISCUSSION

WoodProperty.tw: database content and structure

This study comprehensively compiled wood property data extracted from 156 publications, and integrated the information into a computerized data table. This wood property data table contained 5,762 records and 236 data fields, including physical, mechanical, chemical, wood processing, morphological, and other wood properties (Fig. 1). The category "other wood properties" encompassed miscellaneous properties that did not fall within the five major categories, such as decay resistance, termite resistance, electrical properties, and incombustibility performance (details in Table S2). The table contained considerably more data on physical, mechanical, and morphological properties, with over 2,215 records and 417 species for each (Fig. 1). Data on chemical, wood processing, and other properties were less abundant.

Additionally, a source literature data table and a species information data table were created and integrated with the wood property data table to form a relational database, accompanied by the corresponding metadata for the three tables (Fig. 2). Within the database, each record of wood properties can be traced back to its source literature, providing users with exact reference information. The scientific and vernacular names of tree species were standardized according to the TaiCOL database to adopt the most updated taxonomic information.

Tree species composition in the database

The database collected wood property data for a total of 607 tree species, of which 495 (82%) were native to Taiwan, representing *ca.* 42% of the total native tree species in Taiwan (*cf.* The Editorial Committee of the Flora of Taiwan, 1993–2003). The remaining 112 species were exotic species introduced and cultivated in Taiwan. The top ten species with the most data records (*i.e.*, the most frequently studied species) in the database were: *Cryptomeria japonica*, *Taiwania cryptomerioides*, *Cunninghamia lanceolata*, *Acacia confusa*, *Cu. konishii*, *Chamaecyparis obtusa* var. *formosana*, *Picea morrisonicola*, *Ch. formosensis*, *Pinus taiwanensis*, and *Abies kawakamii*, collectively accounting for *ca.* 23% of the total data records. Notably, nine of these ten species are conifers, most of which are long considered tree species of high timber value (Wang, 1985). The most studied species, Japanese cedar (*Cr. japonica*), is a commercial

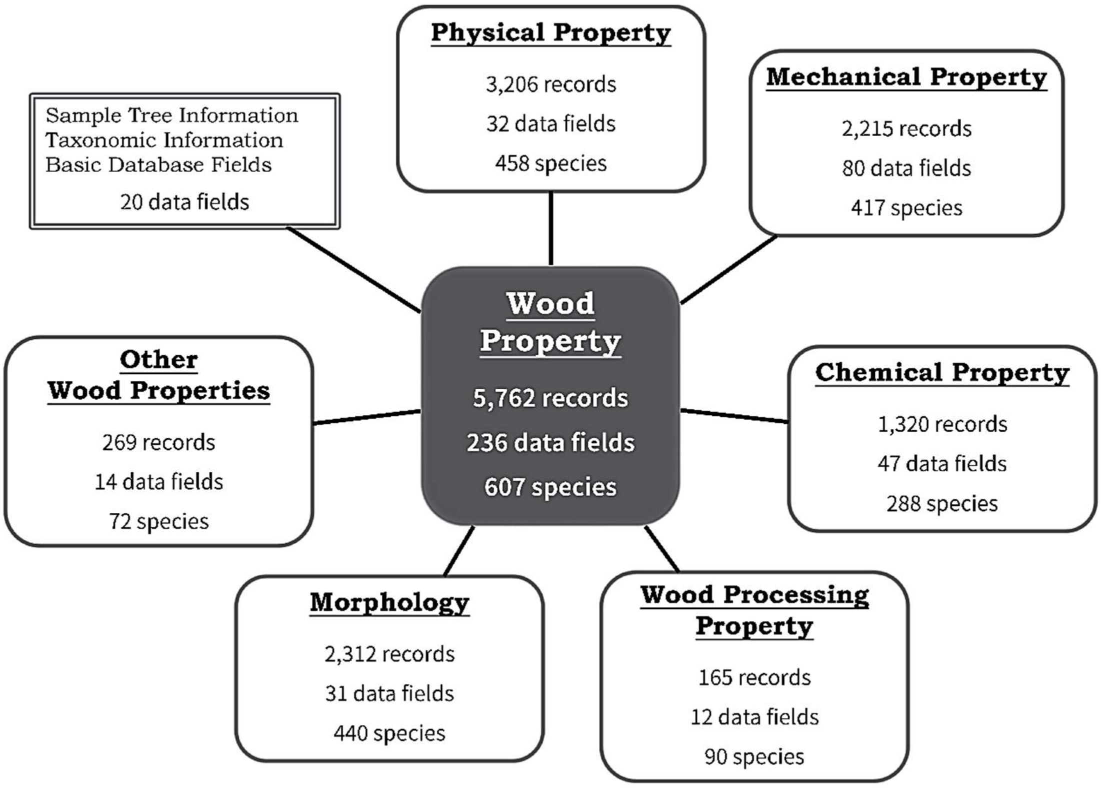

Fig. 1. Content of the wood property data table. The data can be organized into six primary categories, along with 20 supplementary fields for the information of sample trees, taxonomy, and database basics. A data summary is provided for the whole data table and for each category.

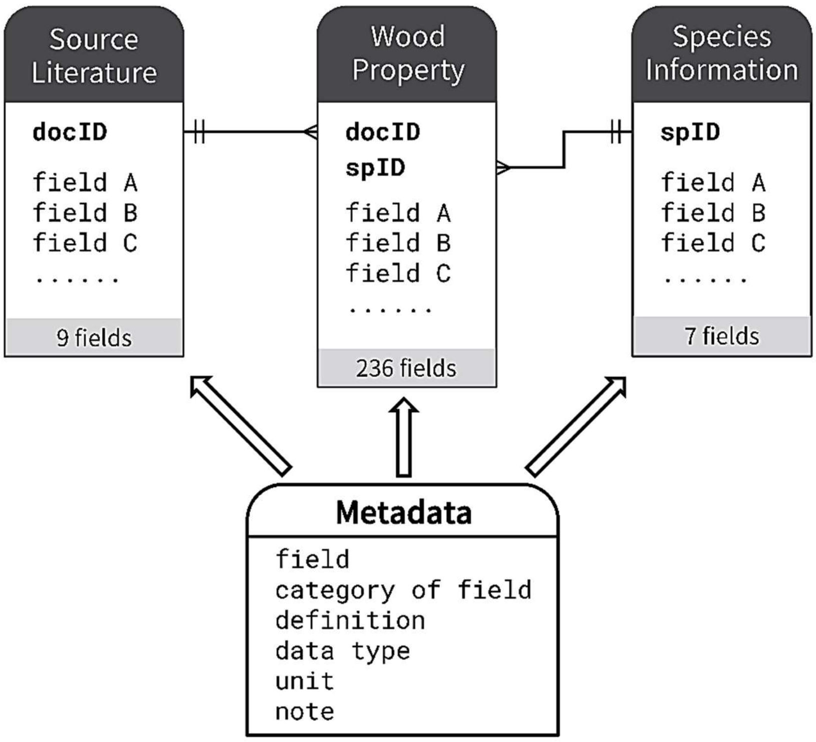

Fig. 2. Diagram of the database structure of the WoodProperty.tw database. Corresponding metadata on the wood property, species information, and source literature data tables are included.

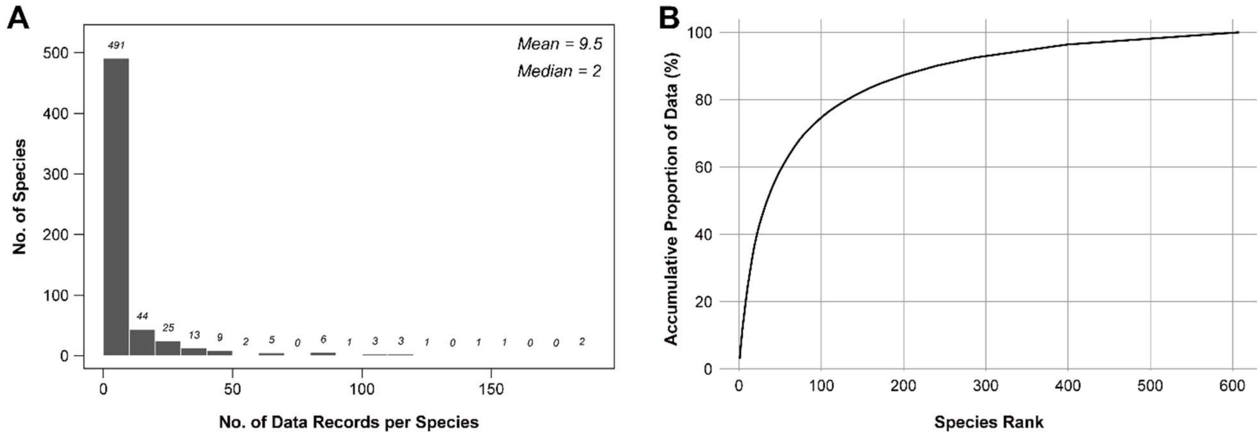

Fig. 3. A. Histogram of data quantity for each species in the database. The mean and median values are provided. The number above each bar denotes the exact number of species; **B.** Accumulative data curve (in proportion) plotted against species ranked in descending order of data quantity.

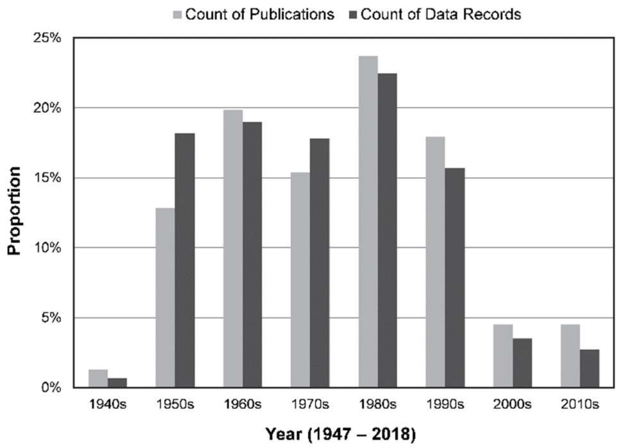

Fig. 4. Proportional changes in the numbers of publications and data records included in the database across different decades (in a total of 156 publications and 5,762 data records, respectively).

wood species introduced from Japan in 1896 and widely cultivated throughout Taiwan (Wang *et al.*, 2013).

The data quantity for each species showed a highly right-skewed distribution, with a mean of 9.5 records and a median of two records (Fig. 3a). Only 11 species (2%) had more than one hundred records, 25 species (4%) had more than fifty records, and 47 species (8%) had more than thirty records. By contrast, 491 species (81%) had less than ten records, and 405 species (67%) had less than five records, showing a sparse data quantity for most species. Even for the more studied species, the data volume is limited. For instance, the most studied species (*Cr. japonica*) contained only 188 data records, representing 3% of the total data volume. Overall, the data distribution across the 607 species showed scarce to limited numbers of data records for each species. Therefore, the accumulative curve of the data volume in the database exhibited a slow and long flattening increase pattern towards the maximum with the expansion of species coverage (Fig. 3b).

When considering the most valuable timber species that have been the major focus of forest management and research in Taiwan, the database contained 182, 124, 119, 115, and 41 data records for the "Five Premium Conifers": *T. cryptomerioides*, *Cu. konishii*, *Ch. obtusa* var. *formosana*, *Ch. formosensis*, and *Calocedrus macrolepis* var. *formosana*, respectively. By contrast, the "Five Premium Hardwoods": *Zelkova serrata*, *Magnolia compressa*, *Camphora officinarum*, *Ca. kanahirae*, and *Sassafras randaiense*, had only 81, 63, 45, 30, and 19 data records, respectively, indicating a lower research intensity for hardwood species.

Trends in wood property research

This database encompassed wood property data collected from 156 publications spanning from 1947 to 2018. An analysis of the data publication year revealed that research on wood properties peaked between the 1950s and 1990s and abruptly declined after 2000, both in terms of the number of publications and the data volume (Fig. 4). A closer examination of the 1990s data showed that there were 28 publications and 903 data records published in this period, with 23 publications (82%) and 801 data records (89%) concentrated in the first three years (1990–1992). That is, the significant decline in research output started after 1992. Reviewing Taiwan's forestry history, the government enacted a revised "Taiwan Forest Management Plan" in October 1991, resulting in a complete ban on logging of natural forests. As the essential experimental material for wood property research, the availability of wood for most native species growing in natural forests has become severely restricted after 1992. It may consequently result in the sharp decline of research activities on investigating the wood properties of tree species in Taiwan.

An analysis of the number of tree species comprised in data from different decades revealed that the 1950s to

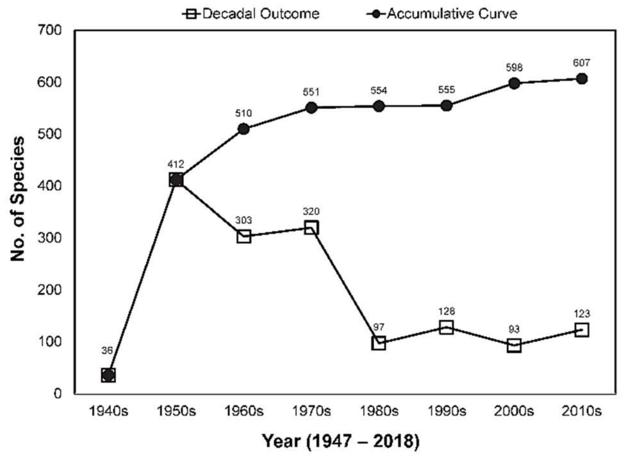

Fig. 5. Changes in the number of species represented in the data over time in the database. The hollow square points indicate the number of species in each decade, while the solid circle points represent the accumulative number of species up to each decade. Each data point is labelled with the corresponding number of species.

1970s was a critical period of rapidly generating wood property data in Taiwan, with 303–412 tree species being collected every decade (Fig. 5). However, starting from the 1980s, although the overall volume of data collected remained substantial (Fig. 4), the number of tree species included drastically declined to around one hundred, resulting in a gradual stagnation in the expansion of the total number of studied species (Fig. 5).

In summary, the research productivity on the wood properties of tree species in Taiwan was profoundly influenced by the history of forest exploitation and the timber industry's demand (*e.g.*, preference for conifers over hardwood species). Forest policies and economic factors may be the major driving forces shaping the trajectory of wood property research in Taiwan. Although wood property research experienced a period of rapid development and accumulation of knowledge since the 1950s, it has notably declined and made limited progress since 1992. Concerning the accumulated wood property data so far, constructing a computerized scientific database should be an essential and foundational work of great application value. This study has overcome this data deficiency and presented a comprehensive wood property database that extensively collects and synthesizes previous research findings from the literature. The database is made ready for use and open access. It can serve as a convenient standard tool, enhancing the accessibility to wood property knowledge of tree species in Taiwan.

CONCLUSION

Despite nearly eight decades of wood science research progress in Taiwan since 1946, a comprehensive digitized database integrating past research findings on wood properties of tree species has been absent. Wood property data generated in previous research works are scattered across printed literature, limiting their accessibility and utilization. Consequently, researchers, forest management agencies, and forest practitioners have faced challenges in obtaining fundamental wood property data for most tree species. This study systematically collects research literature and computerizes wood property data from these sources to construct a synthesized wood property database for tree species in Taiwan. The database, WoodProperty.tw, provides ready-for-use, analyzable, and shareable data, serving as a scientific baseline for forest management and research. Moreover, it can help researchers locate the current gaps in our knowledge of the wood properties of tree species in Taiwan. The database has been deposited in the Zenodo repository (Su, 2025) and is publicly accessible under a Creative Commons Attribution 4.0 License (CC BY 4.0), allowing for free download, use, adaptation, and distribution. When using this database, please cite this data paper and the original publications of the data used.

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