Democratizing essential wood identification information for Central American timber markets with an ergonomically designed, interactive, bilingual smartphone app

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Abstract. In 2022, scientists from the Center for Wood Anatomy Research at the USDA Forest Products Laboratory published a field manual entitled *Identification of Central American, Mexican, and Caribbean Woods*. Bilingual with English and Spanish side-by-side on each page, this publication provided step-by-step processes with simple tools to enable readers with no previous experience in wood anatomy or identification to identify woods of the region. In use, the manual presented potential ergonomic challenges in both print and PDF formats. The objective of this project was to eliminate these challenges by transforming the field manual into a smartphone app. The *WhatWood? Central America* app was built in Visual Studio 2022 using Microsoft's .NET Multi-platform App UI (.NET MAUI). The app is available as a free download on both Android and iOS platforms and can run without an internet connection. Ergonomic modifications included small-screen-optimization, adjustable text, image zooming and panning, and a colorblind viewing option. Dichotomous key navigation was automated, removing the need for manual page turning. Quizzes were added to reinforce the learning of anatomical features. The settings page was configured to show only one language at a time to eliminate the potential for confusion caused by parallel translations. Transforming the original source material into a smartphone application has democratized essential wood identification information for the Central American, Caribbean, and Mexican timber markets by making it available at no cost to virtually anyone in the world with a mobile device, delivering content in both Spanish and English, eliminating potential barriers for operators with mild visual impairments, and providing interactive functionality for self-study.

Keywords: Smartphone app; Wood identification; Illegal logging; Mexico; Caribbean; Central America; Quiz

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Introduction

Exercising due diligence in the responsible management of forest products supply chains requires the assessment and mitigation of risk (PEFC 2020; Wang et al. 2023). Mexico and large parts of Central America[1] and the Caribbean[2] have come under scrutiny in recent years over concerns about illegal logging and wood trade. A 2022 assessment by Forest Trends, a nonprofit organization based in Washington, D.C., categorized 24 out of 27 countries[3] in these regions as medium- or higher-risk for illegal logging and associated trade (Table 1).

Multiple studies have offered evidence suggesting that illegal logging is a problem in Mexico, Central America, and the Caribbean (Buffum 2006; Miller 2011; Mulligan and Bennear 2015; Richards et al. 2003; Torres-Rojo 2021; Vardeman and Runk 2020). Torres-Rojo (2021) estimated that, in Mexico, in the economic census years of 2009, 2014, and 2019, the roundwood-equivalent volume of sawn wood from illegally harvested sources exceeded that of legally harvested materials. Miller (2011) cited studies conducted by the Ministerio de Ambiente y Energía (MINAE) (MINAE 2001) and the Tropical Agricultural Research and Training Center (CATIE) (Campos Arce et al. 2001) reporting that approximately 25%–35% of wood cut and commercialized in Costa Rica is illegal. Richards et al. (2003) estimated that approximately 50% of hardwood timber and 40%–45% of softwood timber produced in Nicaragua are of undocumented origin, and, in Honduras, 75%–85% and 30%–50%, respectively. Vardeman and Runk (2020) highlighted an uptick in illegal logging of cocobolo rosewood (*Dalbergia retusa*) in Panama from the early 2010s. Mulligan and Bennear (2015) estimated that over US$21 million of logs of cedar (*Cedrela odorata*), mahogany (*Swietenia macrophylla*), and rosewood (*Dalbergia* spp.), including Honduran rosewood (*Dalbergia stevensonii*), were illegally harvested in Belize from 2010 to 2012. Buffum (2006) suggested that illegal logging was a major problem in the Forêt des Pins forest reserve in Haiti.

In 2023, the collective export value of fuelwood, industrial roundwood, sawn wood, further-processed wood, wood products for domestic/decorative use, and wood furniture from Central America, Mexico, and the Caribbean exceeded US$2.6 billion (FAOSTAT 2025). As exports of wood products are substantial, concern that illegally harvested materials could be moving between countries in these regions or finding their way into the greater global market is justifiable.

To assist customs inspectors and other control officers in the identification of endangered or controlled species from Central America, Mexico, and the Caribbean, scientists from the Center for Wood Anatomy Research at the USDA Forest Service, Forest Products Laboratory published a revised and expanded

Table 1. Illegal Logging and Associated Trade (ILAT) risk scores and categories for Mexico and countries/territories in Central America and the Caribbean (Forest Trends 2022).

Region	Country/Territory	ILAT Score *	Risk Category
Mexico	Mexico	69.6	Higher
Central America	Honduras	85.7	Higher
	Nicaragua	79.7	Higher
	Guatemala	79.6	Higher
	Belize	65.0	Higher
	El Salvador	54.0	Higher
	Panamá	41.4	Medium
	Costa Rica	30.3	Medium
Caribbean	Haiti	88.7	Higher
	Cuba	65.8	Higher
	Dominican Republic	59.9	Higher
	Trinidad and Tobago	51.4	Higher
	Jamaica	39.8	Medium
	Grenada	39.5	Medium
	Saint Kitts and Nevis	37.5	Medium
	Dominica	37.3	Medium
	Puerto Rico	36.3	Medium
	Antigua and Barbuda	34.9	Medium
	Bahamas	34.3	Medium
	Saint Vincent and the Grenadines	33.9	Medium
	Barbados	31.6	Medium
	Saint Lucia	31.5	Medium
	Aruba	25.4	Medium
	Cayman Islands	28.7	Medium
	Anguilla	17.5	Lower
	Martinique	16.1	Lower
	U.S. Virgin Islands	15.6	Lower

* ILAT scores are based on political, business, government, and corruption data from sources such as the World Bank, United Nations, and others. Scores less than 25 are categorized as "lower-risk," between 25 and 50 as "medium-risk," and greater than 50 as "higher-risk," but scores are relative and should not be interpreted as absolute measures. A summary of data and the methodology used by Forest Trends and the Environmental Investigation Agency (EIA) to determine scores can be found at https://www.forest-trends.org/wp-content/uploads/2021/08/Methodology-for-State-ILAT-Project-Aug-2021-1.pdf.

1. Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panamá.
2. Anguilla; Antigua and Barbuda; Aruba; Bahamas; Barbados; Bonaire, Sint Eustatius, and Saba; British Virgin Islands; Cayman Islands; Cuba; Curaçao; Dominica; Dominican Republic; Grenada; Guadeloupe; Haiti; Jamaica; Martinique; Montserrat; Puerto Rico; Saint Barthélemy; Saint Kitts and Nevis; Saint Lucia; Saint Vincent and the Grenadines; Sint Maarten (French and Dutch parts); Trinidad and Tobago; Turks and Caicos Islands; and U.S. Virgin Islands.
3. Nine of the total 36 mentioned in footnote 2 did not have a risk score or category.

second edition of a field manual for macroscopic identification of common commercial woods from these regions (Arévalo and Wiedenhoeft 2022). Bilingual in English and Spanish, this publication was intended to provide step-by-step processes with simple tools to enable customs officials with no previous experience in wood anatomy or identification to screen wood products with a hand lens and flag suspicious shipments for further forensic investigation in a laboratory. Available in both print and PDF formats, the manual can be used as a tool in both law enforcement and academia, yet it presents potential ergonomic challenges in both paper and electronic formats. To address these challenges, this project reimagined the original publication by transforming it into a smartphone application with added functionality.

Project background

In the late 2000s, the CITES management authorities of Nicaragua and Honduras requested assistance, as part of a Central America-Dominican Republic Free Trade Agreement (CAFTA-DR) implementation plan, from the U.S. Forest Service International Programs. Beginning in 2007, trainers were sent to Central America to teach wood identification workshops on CITES species to customs, military, and government officials responsible for enforcing timber trade regulations in their countries. When author Wiedenhoeft taught a workshop in Honduras, he met with the chief of the newly established National Institute of Forest Conservation, Protected Areas and Wildlife (ICF), Ramón Álvarez, as well as ICF employees Oscar Oqueli and Carla de Martinez, who, having seen the CITES identification guide (Environment Canada 2002), expressed a greater need for a wood identification field manual that covered not only controlled species but also species commonly traded among Central American nations.

To address this need, the U.S. Agency for International Development (USAID), under the CAFTA-DR Environmental Cooperation Agenda, provided funding via the U.S. Forest Service (USFS) International Programs to author a field manual for Central American species from CAFTA-DR countries, with additional support from the U.S. Forest Service, Forest Products Laboratory (FPL) and the Forest Products Society (Wiedenhoeft 2011). Fully bilingual, the publication was laid out in two columns—Spanish on the left and English on the right (Wiedenhoeft 2011). Intended as a tool for customs inspectors and other officials to monitor woods going in and out of their countries, the manual featured an introduction to wood anatomy, step-by-step instructions on how to conduct field identifications with a hand lens, a wood identification key, and species description pages (Wiedenhoeft 2011).

Following the initial publication, workshops across Latin America were supported by USFS International Programs. Although the manual was not intended to be used as an academic reference, it was taken up by some wood anatomy professors at universities in the region (V. Angyalossy, personal communication, June 25, 2013). Chapters of the manual also contributed content to subsequent field identification manuals (Wiedenhoeft and Kretschmann 2014; Arévalo et al. 2020). Several years later, USFS International Programs provided additional funding to expand the number and regional coverage of wood species in the manual from Central America to Mexico and the Caribbean (Arévalo and Wiedenhoeft 2022). This fully revised and expanded second edition increased the number of taxa to 373 species grouped into 138 wood groups or timbers, and more rationally encompassed a coherent biogeographical region.

While the field manual remains a scientifically grounded guide for customs inspectors and other officers to conduct first-level screenings of wood materials with a hand lens, it is not without potential ergonomic challenges in the field. Weighing 1.6 kg, the printed manual is heavier to carry than the typical smartphone (e.g., iPhone 16: 170 g, Apple 2025; Samsung Galaxy S25: 162 g, Samsung 2025) and necessitates manual page turning. Entire PDF pages cannot be legibly viewed on the screens of smaller smartphones, thus requiring users to zoom and pan by pinching and dragging with two hands to view content. The side-by-side bilingual format can be distracting and difficult to navigate, especially for monolingual users. Reformatting the content into a smartphone app has the potential to improve the manual's utility, availability, and accessibility in the field.

Computer-aided wood identification programs

Computer-aided wood identification began in the early 1980s. As innovations such as the personal computer, the graphic user interface, the worldwide web, cellular networks, handheld smart mobile devices, and artificial intelligence emerged over the next four decades, platforms and program features evolved to provide better functionality, availability, accessibility, and interactivity (see Table S1 in the supplement for a more detailed timeline).

Starting in 1980 with IDENT4 (Miller 1980), computer-aided wood identification programs became accessible on time-sharing mainframe computers; by the end of the decade, they had migrated to personal computers, after the release of the IBM PC in 1981, the Apple MacIntosh in 1984, and Windows 1.0 in 1985. Throughout this decade of personal computer innovation and into the mid-1990s, numerous programs and databases, many of which were based on edge-notched/edge-punched cards, were developed for these emerging platforms, e.g., SEARCH (Pearson and Wheeler 1981), CATWI (Tochigi et al. 1984), CARDBOX (Ilic and Hillis 1984), IDENT (Kuroda and Shimaji 1984), IDENT6 (Wheeler and Pearson 1985; Miller et al. 1987), INTKEY (Dallwitz and Paine 1986), MEKA (Duncan and Meacham 1986; Meacham n.d.), GUESS (LaPasha and Wheeler 1987), IAWA-Search (Miller et al. 1987), CARDBOX-PLUS (Ilic 1987; Ilic 1990), SOGEN (Izumoto et al. 1987b, 1988b), IDENTIFY (Kuroda 1987), COMEX (Izumoto et al. 1988a), WIP89 (Jiaju and Fang 1990; Jiaju et al. 2001), IDINEX (Lee and Chun 1990), CSIROID (Ilic 1993), TISS (Chun et al. 1994), and UniWoods 2.0 (Brunner et al. 1995). These early programs introduced much of the functionality that appeared in future wood identification programs and applications, including: on-screen suggestions for characters useful in eliminating remaining taxa, e.g., IDENT4 (Miller 1980), IDENT6 (Wheeler and Pearson 1985; Miller et al. 1987), INTKEY (Dallwitz and Paine 1986), "Microcomputer-based identification program" (Zhang et al. 1986), and CSIROID (Ilic 1993); large databases containing thousands of woods, e.g., SEARCH (Pearson and Wheeler 1981), CARDBOX (Ilic and Hillis 1984), GUESS (LaPasha and Wheeler 1987), IAWA-Search (Miller et al. 1987), CARDBOX-PLUS (Ilic 1987; Ilic 1990), and CSIROID (Ilic 1993); backtracking to and cancelling previous character inputs, e.g., CARDBOX (Ilic and Hillis 1984), IDENT (Kuroda and Shimaji 1984), INTKEY (Dallwitz and Paine 1986), CARDBOX-PLUS (Ilic 1987; Ilic 1990), and CSIROID (Ilic 1993); displaying example images of wood anatomical features, e.g., "Microcomputer-assisted Wood Identification System" (Izumoto et al. 1987a; Izumoto and Hayashi 1990), SOGEN (Izumoto et al. 1987b, 1988b), and WIP89 (Jiaju and Fang 1990; Jiaju et al. 2001); and, providing detailed, written explanations of wood anatomical features, e.g., "Microcomputer-assisted Wood Identification System" (Izumoto et al. 1987a; Izumoto and Hayashi 1990), SOGEN (Izumoto et al. 1987b, 1988b), and CSIROID (Ilic 1993).

With the advent of the Worldwide Web in the 1990s, web-based applications began to appear in the early 2000s, e.g., Commercial Timbers (Richter and Dallwitz 2000 onwards), Anatomy of European and North American Woods (Heiss n.d.), Wood Database of the Forestry and Forest Products Research Institute (Forestry & Forest Products Research Institute n.d.), InsideWood (InsideWood 2004 onwards; Wheeler 2011; Wheeler et al. 2020), and Wood Anatomy of Central European Species (Schoch et al. 2004). Following the release of the Apple iPhone in 2007 and the first version of the Android operating system in 2008, the first smartphone-based wood ID program launched on iOS in 2009: I.D. Wood (Jordan Silberman 2009). Smartphones offered numerous advantages over previous platforms, including improved portability, single-handed operation, optimized displays, adjustable text sizes, automatic updates, and now near ubiquitous availability. Publishing of manual, key-based apps continued through the 2010s and into the 2020s, e.g., macroHOLZdata (Sven Koch 2016), Xylorix PocketWood (Agritix Sdn Bhd 2020a,b), CITESwoodID (Sven Koch 2020), and ID Maderas (UNODC 2021). In 2018, automated wood identification programs using computer vision also began to emerge, e.g., MyWoodPremium (formerly MyWood-ID; INSTITUT PENYELIDIKAN DAN PERHUTANAN MALAYSIA 2018), Xylorix Inspector (Agritix Sdn Bhd 2018), AIKO-KLHK (AIKO-KLHK Dev 2019), Xylorix Enforcer (Agritix Sdn Bhd 2022), and WoodID App (Khanh Nguyen Trong 2024).

While computer-vision-based applications provided a means for users less familiar with conventional macroscopic techniques to perform wood identifications, there remained a need for traditional key-based programs. For example, the ISO 17020:2012 workflow and instructions for the Timber Industry Development Division (TIDD) of the Ghana Forestry Commission timber inspectors still prescribe the use of manual inspection techniques (Eshun et al. 2017) and rely on a specific publication (Arévalo et al. 2020) for their wood identification work.

Project objectives

The objective of this project was to improve the utility, availability, accessibility, and flexibility of the original wood identification field manual Identification of Central American, Mexican, and Caribbean Woods (Arévalo and Wiedenhoeft 2022) by utilizing smartphone app functionality to eliminate potential ergonomic challenges inherent to static print and PDF publication formats. The project's specific goals were to:

1. Release the app in both Spanish and English to maximize linguistic accessibility.
2. Present content one language at a time to prevent the potential for confusion caused by parallel translations and the resultant diminution of text size or need for panning when languages are presented side-by-side.
3. Adapt the manual's visual and textual elements to automatically fit any smartphone or tablet display.
4. Equip the app with adjustable accessibility settings for users with mild visual impairments.
5. Empower users to navigate and scroll using only one hand.
6. Automate decision-tree routing for the wood identification key.

7. Enhance the wood identification key with zoom- and pan-capable reference images.
8. Enable automatic dissemination of content updates to users' smartphones.
9. Simplify the revision process, allowing authors to continually improve content as a result of #8.
10. Offer the app free of charge on both Android and iOS platforms.
11. Supply all content within a native app, eliminating the need for internet access in the field post-installation.
12. Introduce interactive functionality for learning wood anatomical features through quizzes.

Materials and methods

Source publication

WhatWood? Central America Edition is largely based on the original source publication entitled *Identification of Central American, Mexican, and Caribbean Woods* (hereafter "the field manual," or simply "the manual"; Arévalo and Wiedenhoeft 2022). Organized into eight chapters, the manual covers topics such as basic wood anatomy, features and techniques used in wood identification, surface preparation of specimens, proper hand lens use, description pages for 138 species groups (hereafter "woods"), and a dichotomous wood identification key.

Images

The high-resolution PDF version of the manual was the source of all specimen images. Each was extracted and saved with Adobe Acrobat at a resolution of 721×721p. Screenshots were taken of all figures and tables at 1920×1080p. In all, 929 specimen images and 59 screenshots of figures and tables were used in the app.

Text

The field manual was also the source of most of the app's text. The text concerning wood anatomy and macroscopic wood identification from Chapters 1 through 5 and Chapter 8 was saved as resource (.resx) files with Adobe Acrobat. Using the same software, the text for the wood identification key (Chapter 6), species description pages (Chapter 7), and anatomical feature index was saved as text files (.txt), along with the key's navigation routes.

Framework

Visual Studio 2022 was used to build the app with Microsoft's .NET Multi-platform App UI (.NET MAUI). This framework allows projects to be complied into native Android, iOS, macOS, Windows, and Samsung Tizen apps by a single code base (alvinashcraft et al. 2025; davidbritch et al. 2025) using XAML for markup and C# for code-behind. Of these platforms, the authors chose to compile and distribute the app for Android, iOS, and macOS. Resulting .NET MAUI apps are backward compatible to Android version 5.0 (Lollipop), iOS version 12.2, and macOS version 11.0.

Database

Resource and text file data were imported into an SQLite database (SQLite Developers 2025). The database was managed by Microsoft's Entity Framework Core (EF Core) object-relational mapper (SamMonoRT et al. 2024), allowing the .NET MAUI app to interact with and retrieve data from the database.

Anatomical feature quizzes

To familiarize users with the wood anatomical features referenced in the manual's dichotomous identification key, two interactive quizzes were created: a choice quiz and a feature selection quiz. In the choice quiz, users are shown pictures of two different woods and prompted to choose the wood that displays a particular anatomical feature. In the feature selection quiz, users are shown a single picture of one wood and asked to choose from a list all anatomical features that appear in the image.

To enable image queries based on anatomical characteristics, numerical codes for the features detailed in the species descriptions were added to the database for every wood. For instance, *Cedrela* spp. were coded for the presence of distinct growth ring boundaries (coded as 1); semi-ring-porosity (coded as 4); medium-to-narrow rays (coded as 97); average ray abundance (coded as 115); apotracheal diffuse parenchyma (coded as 76); paratracheal vasicentric parenchyma (coded as 79); and marginal parenchyma (coded as 89). Anatomical features were also grouped by category. For instance, the features "distinct growth ring boundaries" and "indistinct or absent growth ring boundaries" were assigned to the category "growth ring boundaries," while the features "narrow rays," "medium-to-narrow rays," "wide rays," and "very wide rays" were assigned to the category "ray width."

Choice quiz. The choice quiz generates question pages through an in-app initialization process. First, a random anatomical feature code (e.g., 89) is chosen. The question is created by displaying that feature's name ("marginal parenchyma") after the phrase "Which species displays…" (see Figure 1, upper right). Next, the app queries the database with this code to randomly select two woods: one with the feature (e.g., *Cedrela*

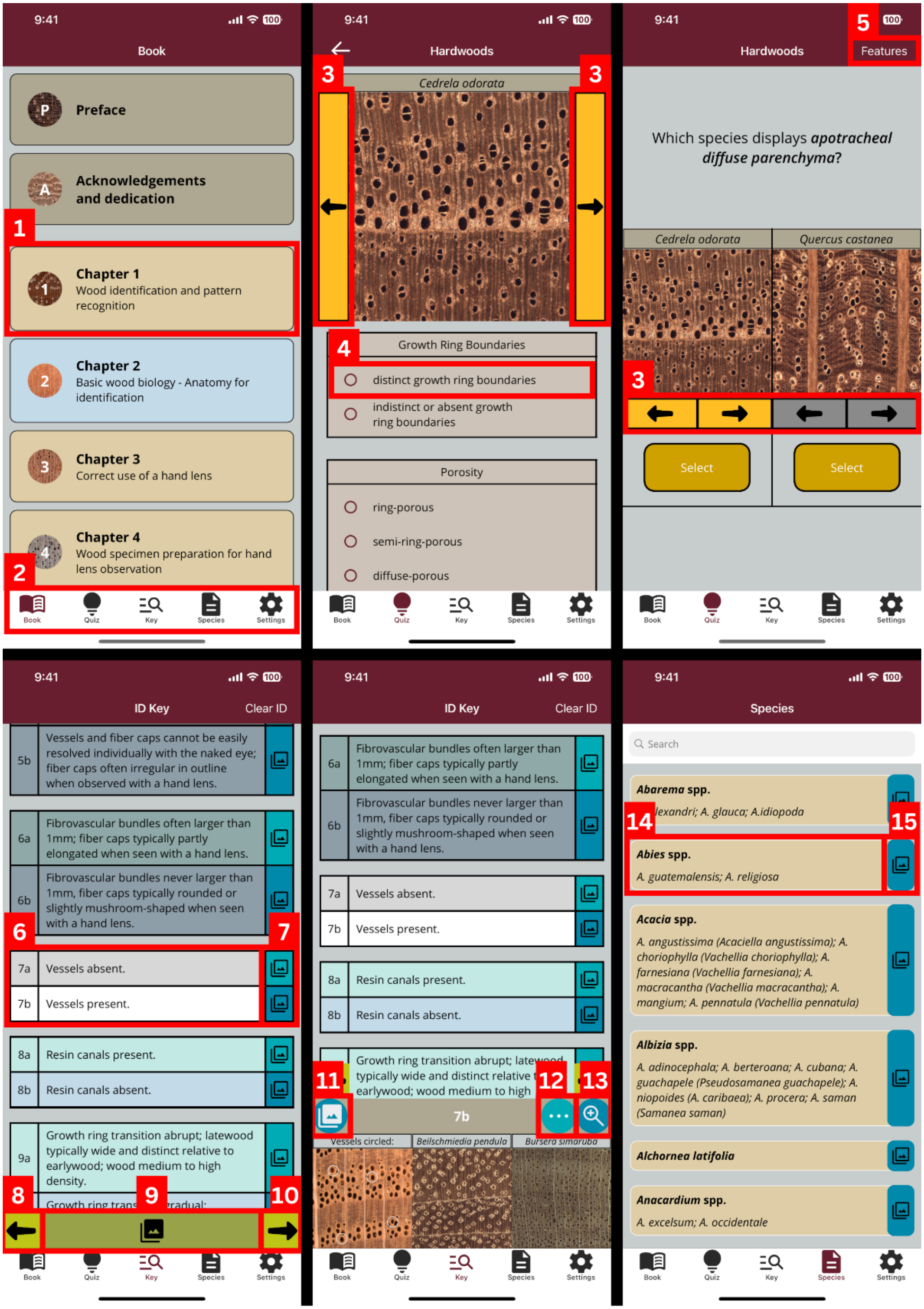

Figure 1. Buttons that appear in the *WhatWood? Central America Edition* app. (1) Chapter button. (2) Tab bar. (3) Arrow buttons. (4) Check box. (5) Features button. (6) Option buttons. (7) Example buttons. (8) Back button. (9) Image button. (10) Forward button. (11) Round image button. (12) More button. (13) Zoom button. (14) Wood button. (15) Preview button.

sp.) and one without (e.g., *Vochysia* sp.). Then, an image for each wood is retrieved via the database. The image showing the feature is randomly positioned on the left or right, with the other image filling the remaining spot. Both images are labeled with their scientific names. Finally, after the user selects an image, a results screen indicates if the answer is correct. New questions are then generated using the same initialization process.

Feature selection quiz. The question pages for the feature quiz are generated through a disparate in-app initialization process. First, a random database query returns a list of anatomical features for a particular wood (e.g., *Cedrela* sp.: distinct growth ring boundaries, semi-ring-porosity, medium-to-narrow rays, average ray abundance, apotracheal diffuse parenchyma, paratracheal vasicentric parenchyma, and marginal parenchyma). A second query makes a list of categories those features represent (i.e., the categories of growth ring boundaries, porosity, ray width, ray abundance, apotracheal axial parenchyma, paratracheal axial parenchyma, and banded parenchyma). A third query makes a list of all possible features for every feature category represented. A final query returns a list of images of the selected wood. To fill out the page, an initial image of that wood is positioned near the top, headed by its scientific name (Figure 1, upper middle). Below the image appears a scrollable list of features separated into sections by category. Each section contains two or more anatomical features belonging to that category formatted as check boxes. After the user makes his/her feature selections and taps submit, the result is displayed. The initialization process repeats for each subsequent question.

Beginning each initialization with a random query reduces the likelihood that the same questions with the same images will appear in the same order. This ensures a novel experience every time a new quiz is started.

Results

The app, *WhatWood? Central America Edition,* is available free of charge on the Google Play Store[4] and Apple App Store.[5] It is downloadable to both Android and iOS devices with a minimum available storage of 190 MB and 342 MB, respectively. Once installed, the app can run without an internet connection. The .NET MAUI source code can be viewed on GitHub at (https://github.com/msu-whatwood).

4. Google Play Store: https://play.google.com/store/apps/details?id=com.MSUwoodID.camcwoods&hl=en_US)
5. Apple App Store: https://apps.apple.com/iq/app/whatwood-central-america-ed/id6737476229

The user-interface (UI)

Figure 1 shows the button types that appear in the app. References to these button types are bolded in the paragraphs below.

The app is organized into five sections, each accessible from the **tab bar** at the bottom of every screen: (1) "Book" (represented by the book icon) containing all the text and images from the original field guide organized by chapter; (2) "Quiz" (lightbulb icon) offering two self-study quizzes on anatomical features; (3) "Key" (magnifying glass icon) providing the interactive dichotomous wood identification key; (4) "Species" (dog-eared document icon) including all the individual species description pages from the original manual; and (5) "Settings" (gear icon) where users can customize the app's interface and find the credits.

Book tab

The Book tab provides access to the complete contents of the original field manual, including text and images, except for Chapters 6 and 7, which are represented by the key tab and species tab, respectively. The main page presents a table of contents by chapter (Figure 2A). The user can open any chapter by tapping its **chapter button** (Figures 2A and 2B). Tapping on an image will open it in a separate screen where the user can zoom (pinch gesture) and pan (drag gesture) for closer examination.

Quiz tab

To aid users in recognizing the kinds of anatomical features described in the dichotomous key, the Quiz tab provides two interactive learning modes: the choice quiz and the feature selection quiz. The choice quiz (Figure 3A) displays an anatomical characteristic and a pair of images. The user is asked to select the image exhibiting that characteristic. The **arrow buttons** below each image enable the user to browse additional images of the same woods. Each selection results in a pop-up message indicating whether the answer was right and showing a running total of correct responses (Figures 3B and 3C).

Accessible via the **features button** in the top right of the choice quiz (Figure 3A), the feature selection quiz (Figure 3D) presents an image of one wood and asks the user to identify all features exhibited in that image by selecting the corresponding **check boxes**. Similar to the choice quiz, **arrow buttons** allow the user to view other images of the same wood. After each attempt, a pop-up message provides feedback on the number of correctly identified features (out of the total possible) as well as tallies of any correct features missed and any incorrect features chosen (Figures 3E and 3F).

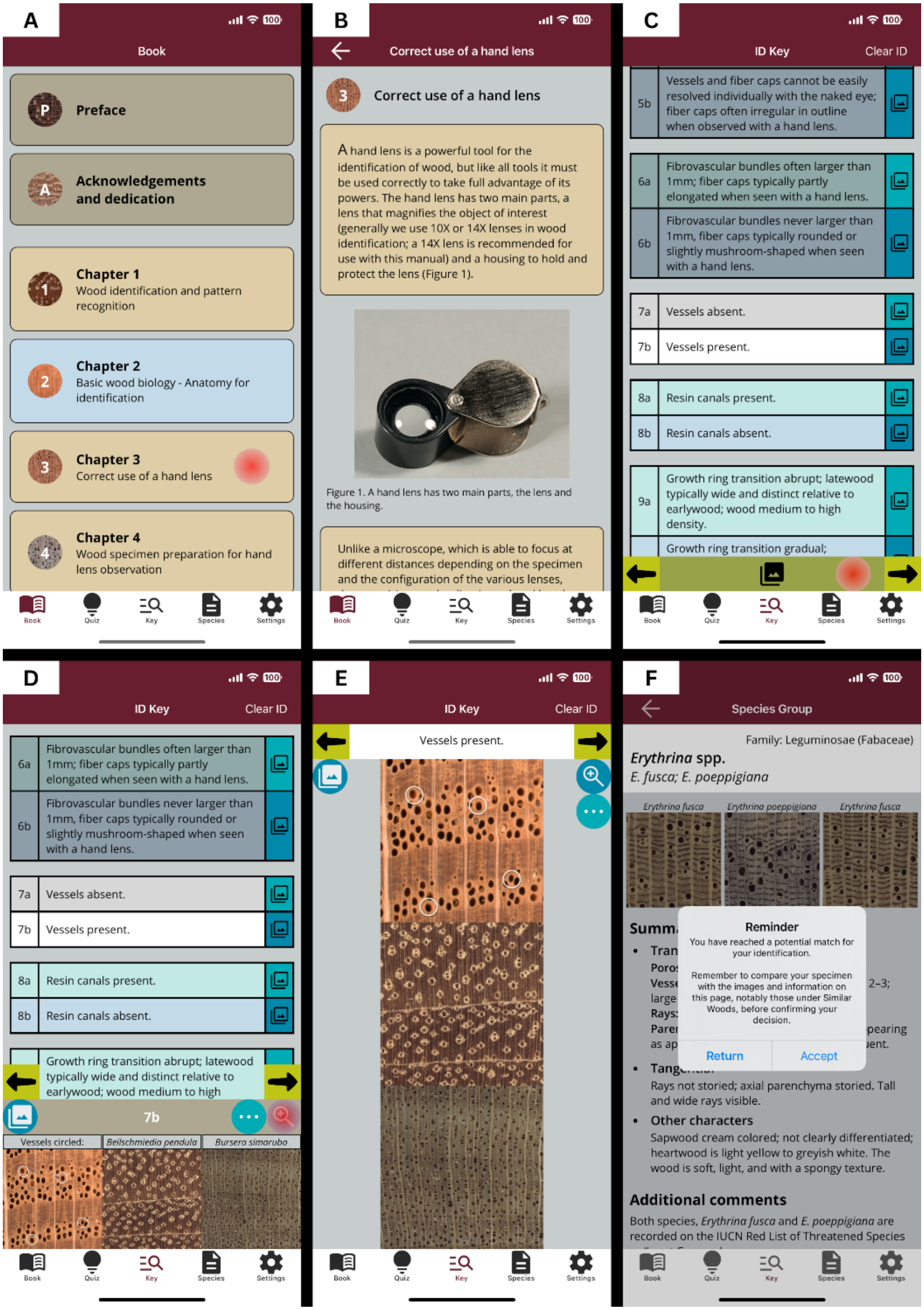

Figure 2. Pages in the Book tab (A, B) and the Key tab (C, D, E, F) of the *WhatWood? Central America Edition* app. Circular red highlights on A, C, and D signify a user's tap and the following in-app navigation to a subsequent page. (A) Book tab showing the first part of the table of contents (the rest of the TOC can be accessed by scrolling down the screen). (B) Book page for Chapter 3. (C) Dichotomous wood identification key. **Option buttons** appear in couplets, requiring the user to choose one to proceed to the next couplet. (D) Exemplar images in expanded view in the interactive dichotomous key. (E) Full-screen exemplar images in the interactive dichotomous key. The images can be examined in detail by zooming and panning with pinch and drag gestures, respectively. (F) Pop-up message reminding the user to compare their specimen with the images, information, and similar woods listed on the description page before confirming the classification.

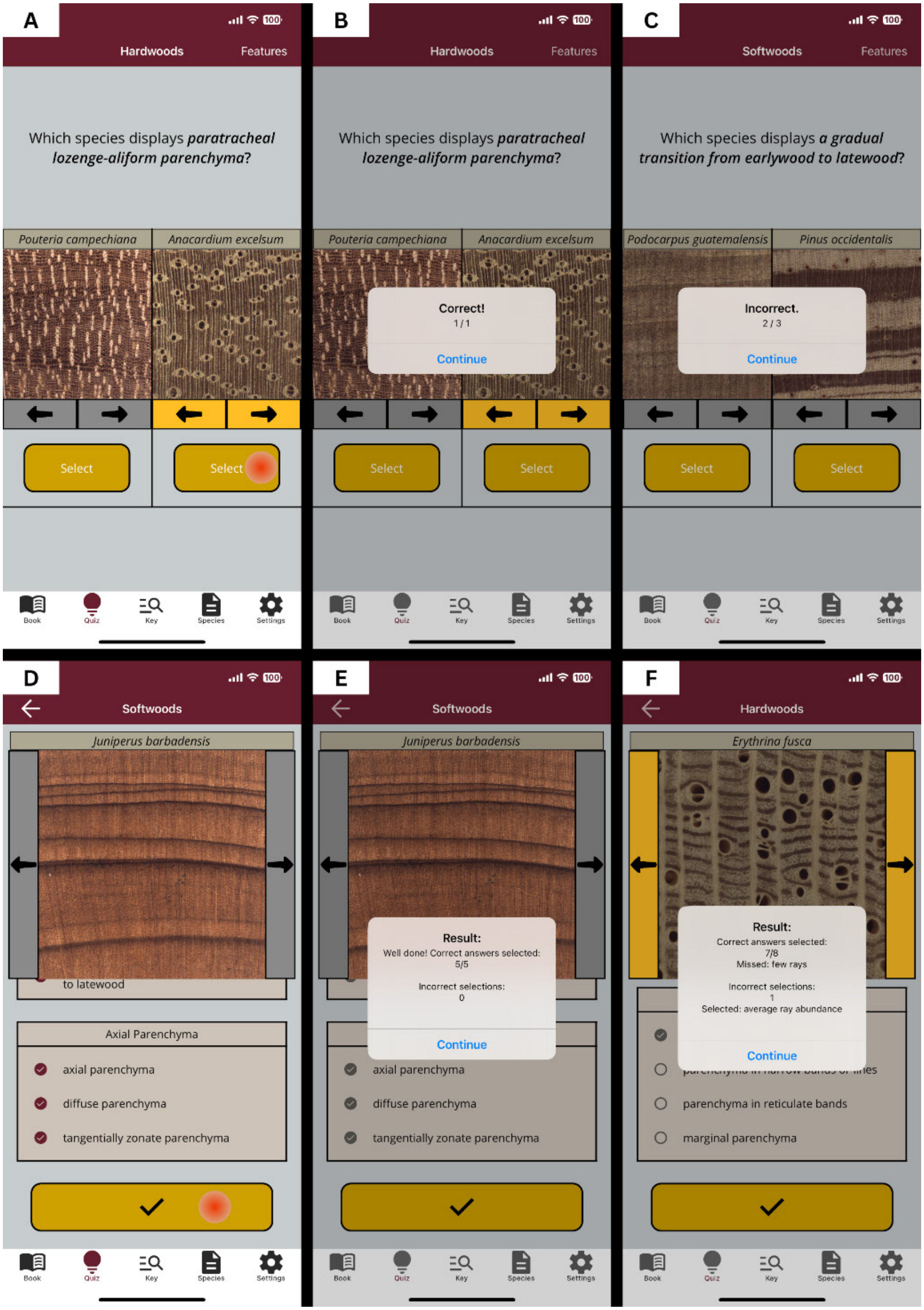

Figure 3. The choice quiz page (A, B, C) and the feature selection quiz page (D, E, F) in the *WhatWood? Central America Edition* app. Circular red highlights on A and D signify a user's tap and the following in-app navigation to a subsequent page. (A) Choice quiz. Arrow buttons under the images allow users to cycle through additional images of each wood. (B) Pop-up message for the choice quiz with running total of correct responses per total attempted questions. (C) Pop-up message for the choice quiz following two correct responses and a final incorrect response. (D) Feature selection quiz. (E) Pop-up message for the feature selection quiz following a user selecting every correct feature and no incorrect features. (F) Pop-up message for the feature selection quiz stating the numbers of correct and incorrect features selected as well as listing the correct features missed and the incorrect features selected.

Key tab

The Key tab provides access to the interactive dichotomous wood identification key. It opens to a scrollable series of **option buttons** arranged in pairs. Each button is labeled with an anatomical feature description representing one of two choices. When an option is selected, the interface automatically scrolls to the next pair of choices in the decision tree, skipping the no-longer-relevant options *en route*. The black-on-green **back** and **forward buttons** just above the **tab bar** (Figure 2C) allow users to backtrack or return one or more steps in the key without having to restart from the beginning.

Tapping the dark green **image button** with the black image icon centered just above the **tab bar** (Figure 2C) opens an expanded view revealing specimen images to supplement the feature descriptions in each **option button**. Users can alternate between image sets for each feature description by tapping the **blue example button** with the black image icon to the right of each **option button** (Figure 2D). For each feature description with more than one associated image set, the **more button** appears at the top of the expanded view, allowing users to view additional specimen images for the same description. By tapping the **magnifying glass button** (Figures 2D and 2E), users are able to zoom and pan images in a separate full screen page (Figure 2D). Tapping the **blue image button** in the upper left of the expanded view (Figures 2D and 2E) causes it to close.

Upon making a terminal decision, a species page automatically opens along with a pop-up message encouraging users to compare their specimen with the information and images on that page before finalizing their conclusion (Figure 2F). To facilitate additional comparisons, similar woods are illustrated at the bottom of the page.

Species tab

The Species tab gives users the option to select and view description pages for each wood. Navigation begins on the index page where users can choose from a series of **wood buttons**, each labeled with the included scientific names (Figure 4A). Each **wood button** can be expanded to reveal three exemplar images by tapping the **blue preview button** on the right (Figure 4A). By tapping an exemplar image, the user can view a larger version in full screen where it can be zoomed and panned. Woods can be filtered by scientific name by using the search bar at the top of the index page (Figure 4B). Users can open a species description page by tapping the **wood button** for that taxon (Figure 4C). Images of lookalike woods appear at the bottom of each page (when applicable) to facilitate comparisons. User notes can be saved in the large text box at the bottom of each species page, and these notes are carried over when the user changes the language setting.

Settings tab

The Settings tab provides customization options for the app's appearance (Figure 4D) and access to the author credits via a dedicated button (Figure 4F). From here, users can adjust the font size (8–24 point) or increase the visual contrast of elements in the tab bar and navigation bar by switching to colorblind mode, improving usability for individuals with color vision deficiency (CVD) (Jamil and Denes 2024) (Figure 4E). To further support users with CVD, all buttons in the app exhibit icons or text labels to ensure color is not the only way to convey information or distinguish elements (World Wide Web Consortium 2024). The scrolling animation for the wood identification key can be toggled on (default) or off from this page. When enabled, tapping an **option button** executes a scroll animation to the next couplet; when disabled, the key advances to the next couplet without scrolling. Users can also select their preferred launch from among the Key (default), Book, Quiz, or Species tabs.

Discussion

Without rigorous field trials or comparative assessments—neither of which were feasible at present due to logistical and cost limitations—it was not possible to draw definitive, scientific conclusions about the degree to which *WhatWood? Central America Edition* has improved or enhanced the user experience. Until such testing can be conducted, the authors offer the following summary of objectives achieved. Any statements of improvement or enhancement presented herein are either logical outcomes of the app design or expected impacts.

Available free of charge on both the Google Play Store and the Apple App Store, anyone with an Android or iOS device can now download *WhatWood? Central America Edition* at no cost from virtually anywhere on the planet at any time, effectively democratizing access to the content first presented in *Identification of Central American, Mexican, and Caribbean Woods* (Arévalo and Wiedenhoeft 2022). Unlike print or PDF publications, the app can receive content updates automatically. This has the potential to make the revision process less burdensome, costly, and time consuming for developers. Once installed, the native app can function without an internet connection even in the remotest of areas.

Ergonomic modifications have the potential to improve the app's usability and accessibility over print and PDF versions. Choosing a language on the Settings tab removes the

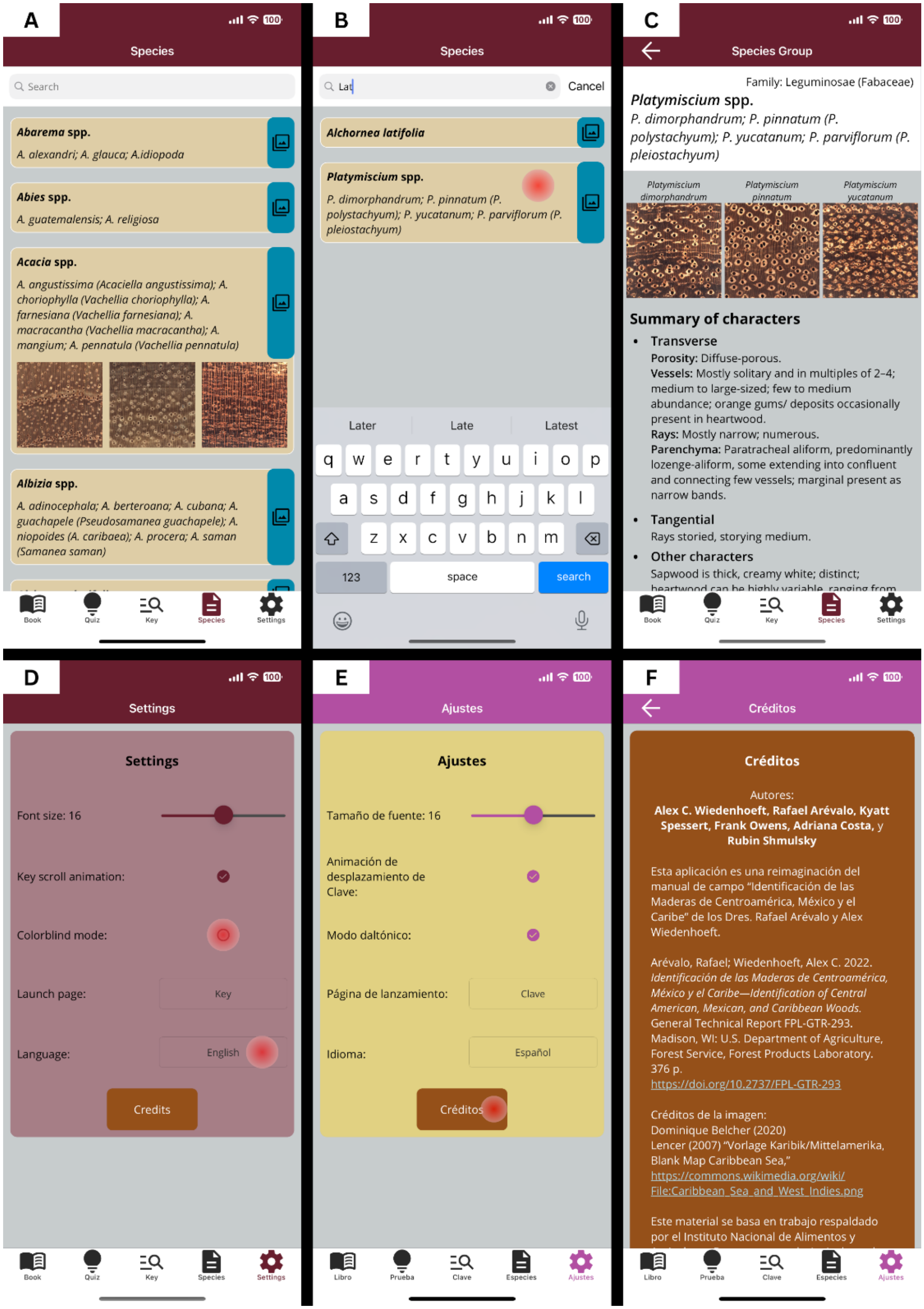

Figure 4. Pages in the Species tab (A, B, C) and the Settings tab (D, E, F) of the *WhatWood? Central America Edition* app. Circular red highlights on B, D, and E signify a user's tap and the following in-app navigation to the subsequent page. (A) Species index page with preview images for *Acacia* spp. revealed. (B) Example search for "Lat" on the species index page. (C) Species description page for *Platymiscium* spp. including images and descriptions. (D) Settings page. (E) Settings page with colorblind mode enabled and Spanish language selected. (F) Credits page with colorblind mode enabled and Spanish language selected.

Figure 5. One-handed use of *WhatWood? Central America Edition.*

other language from the interface, eliminating any potential difficulties resulting from side-by-side Spanish and English translations. The content is thus available not only to native speakers of Spanish and English but also to the millions of potential users for whom Spanish or English is an additional language. Owing to the automatic optimization of text and images to fit smartphone or tablet screens of any size, users no longer have to pinch and drag to view and navigate page content, yet the addition of expanded views and full screen images allows for zooming and panning when needed. Font sizes are no longer fixed, allowing users with visual impairments to enlarge text via the Settings page. For users with CVD, a high-contrast colorblind mode is also available. Manual page turning has been replaced by finger scrolling. Dichotomous key navigation can be executed with one hand via automatic decision routing, potentially reducing the likelihood of human error and allowing the user to hold a specimen or hand lens in the opposite hand (Figure 5). Terminal decisions result in the automatic opening of species description pages expediting access to critical information. Static, conventional learning of essential anatomical features from the Book tab has been supplemented with interactive quizzes that can turn even a few minutes of free time into a focused study session.

Suggestions for future work

Enhancing the educational components of *WhatWood? Central America Edition* could potentially add greater value. To improve engagement, understanding, and retention (Bai et al. 2020; Hamari et al. 2014; Kapp 2012), the interactive functionality of the anatomical feature quizzes could be further expanded to include gamified elements such as badges, personal best scores, skill rankings, etc. Video content could also be incorporated into the app to provide quick-start usage tutorials and more in-depth visual descriptions of anatomical characteristics. As many of the woods that appear in the app are also common to Brazil, the addition of a third language, Portuguese, might increase the size of its audience substantially.

Future integration with computer-vision wood identification (de Andrade et al. 2020; Hwang and Sugiyama 2021; Ravindran et al. 2020; Yi Tou et al. 2007) could be employed in conjunction with the inspector's manual identification as a preliminary identification or a final step to bolster field identification.

Conclusion

Transforming the original source material into a smartphone application has democratized essential wood identification information for the Central American, Caribbean, and Mexican timber markets by making it available at no cost to virtually anyone in the world with a mobile device, delivering content in both Spanish and English, minimizing potential barriers for operators with mild visual impairments, and providing interactive functionality for self-study. *WhatWood? Central America Edition* has also demonstrated the potential for converting and enhancing a wide array of print publications into more modern, accessible, intuitive, and ergonomic digital products that can further empower the frontline defenders policing illegal logging and commercial fraud.

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The authors ask that any use or adaptation of the code for *WhatWood? Central America Edition* will include clear reference to and citation of this paper, and credit for the app source code.

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Supplement: Table S1. Summary of computer-aided wood identification programs.

Date	Same-year historical milestones	Program name	Developer(s)	Platform or OS	References *	Purpose	Scope	Functionality
1980		IDENT4	L.E. Morse	Time-sharing computers	Morse 1971; Morse 1974; Miller 1980	General taxonomic ID	Hardwoods (number & regions unspecified)	Int. M-E Key; lists useful characters for separating remaining taxa & allows setting a character mismatch limit.
1981	IBM PC released	SEARCH	R.G. Pearson & E.A. Wheeler	Mainframe computer	Pearson and Wheeler 1981	Hardwood ID based on Metcalfe & Chalk's perforated cards (1950)	4724 hardwood entries, global	Non-Int. M-E Key that performs batch operations; allows specifying a minimum number of matches for entered characters.
1983		Adaption of IDENT4	J.T. Quirk	Time-sharing computers	Quirk 1983	ID of commercial Asian & Australian Leguminosae species	39 species of Asian & Australian Leguminosae	Int. M-E Key; lists useful characters for separating remaining taxa & allows setting a character mismatch limit.
1983		"Domestic Hardwood Identification System"	M. Hasegawa	NEC PC-8801	Hasegawa 1984	Microscopic ID of Japanese hardwoods based on Sudo's punched cards (1959)	59 domestic Japanese hardwood species	Non-Int. M-E Key that performs batch operations; allows entering unknown/"wildcard" characters.
1984	Apple releases Macintosh	Computer Assisted Tropical Wood Identification (CATWI)	T. Tochigi, T. Shiokura, C.B. Lantican, C.G. Salud, & C.B. Madamba	Hitachi PC-9801	Tochigi et al. 1984	Tropical hardwood ID intended for non-expert wood anatomists; based on set theory	Tropical hardwoods (number & regions unspecified)	M-E Key that presents characters in order of their ease of observation & suitability for separating remaining woods in two.
1984		CARDBOX (CSIRO Microcomputer Wood Identification Database)	CSIRO Australia	CP/M-80	Ilic and Hillis 1984	Hand lens & microscopic ID of primarily southwest Pacific & Australian woods	About 5000 taxa, primarily of the southwest Pacific & Australia; 14 total macro/micro keys	Int. M-E Key that allows sorting taxa by presence or absence of characters, searching for terms used in taxa descriptions, & backtracking to previous character inputs.
1984		IDENT	K. Kuroda & K. Shimaji	CP/M, NEC PC-9801, & Fujitsu FACOM OS IV/F4	Kuroda and Shimaji 1984	Commercial Japanese hardwood ID based on Sudo's punched cards (1959) & coded according to the IAWA Standard List (1981)	Commercial Japanese hardwoods reported by Sudo (1959) (number unspecified)	Int. M-E Key that displays the number of remaining taxa & allows backtracking to previous character inputs; accessible in Japan via telephone call.
1985	Microsoft releases Windows 1.0	IDENT6	Department of Wood and Paper Science, North Carolina State University	PC	Wheeler and Pearson 1985; Miller et al. 1987	Further iteration of the IDENT4 program featuring usability improvements	Hardwoods (number & regions unspecified)	Same as IDENT4, w/ improvements: users can enter more characters at once, search for exact matches of characters, & obtain individual taxa descriptions & character states.
1986		INTeractive KEY (INTKEY)	M.J. Dallwitz & T.A. Paine	Mainframe computers & microcomputers	Dallwitz and Paine 1986	General taxonomic ID using DEscription Language for TAxonomy (DELTA) formatting	General biological taxonomy	Int. M-E Key that allows entering multiple characters, obtaining possible matches at any time, & viewing useful features for distinguishing remaining taxa.
1986		Multiple-Entry Key Algorithm (MEKA)	T. J. Rosatti, R. Phillips, D. Hough, T. Duncan, & C.A. Meacham	CP/M & MS-DOS	Duncan and Meacham 1986; Meacham n.d.	Hardwood ID to family based on punched-card key data of Hansen and Rahn (1969, 1972, 1979) and of Simpson and Janos (1974)	Global angiosperm & dicot families of the Western Hemisphere, south of North America (number unspecified)	M-E Key that provides IDs to one or a set of taxa, listing taxa lacking up to five entered characters; lists shared & individual characters among sets of taxa.
1986		General Unknown Entry and Search System (GUESS)	C.A. LaPasha	DOS & Macintosh	LaPasha and Wheeler 1987	General taxonomic ID; derived from the SEARCH program	5260 entries of global hardwoods, softwoods, & fibers	M-E Key that performs batch operations & allows mismatches.

Supplement: Table S1. Summary of computer-aided wood identification programs (*continued*).

Date	Same-year historical milestones	Program name	Developer(s)	Platform or OS	References *	Purpose	Scope	Functionality
1986		"Microcomputer-based identification program"	Q.C. Zhang, F. Cheng, & Y.H. Lian	Microcomputers	Zhang et al. 1986	Microscopic Chinese hardwood ID based on punched-card keys of the Wood Industry Research Institute of the Chinese Academy of Forestry (1983)	Chinese hardwoods (number unspecified)	M-E Key that allows searching by characters and species names, specifying character absence, & obtaining characters for narrowing remaining taxa; uses an indexed DB for quick searching.
1987		IAWA-Search	C.A. LaPasha	PC	Miller et al. 1987	Searching the IAWA-OPN DB of global hardwoods; derived from the SEARCH program	~3500 hardwood species, global scope; SEARCH's DB adapted to the IAWA Standard List (1981)	M-E Key that searches its DB quicker than the IDENT4 & IDENT6 programs but lacks some of their features.
1987		"Microcomputer-assisted Wood Identification System"	Y. Izumoto, T. Ojika, T. Kakimoto, & T. Watanabe	NEC PC-9801	Izumoto et al. 1987a	Macroscopic Japanese wood ID & display of wood images & diagrams, aimed at beginner/non-expert wood anatomists	32 hardwood & 18 softwood species of Japan	Interactive dichotomous key that displays diagrams of wood characters, includes a glossary & written tutorials on its use & interpreting characters, & provides microphotographs & color surface images of included woods.
1987		CARDBOX-PLUS (CSIRO Family Key)	CSIRO Australia	PC	Ilic 1987	ID of hardwoods to family, w/ a focus on the southwest Pacific & Australia	152 hardwood families, primarily of the southwest Pacific; includes keys used in CARDBOX	Int. M-E Key that allows exclusion of characters, displaying the sequence of entered characters, & cancelling previous character inputs.
1987		SOGEN	Y. Izumoto, T. Ojika, & T. Hashimoto	NEC PC-9801UV2	Izumoto et al. 1987b	Macroscopic ID of domestic Japanese hardwoods	32 Japanese hardwood species	Int. M-E Key that presents characters in order of frequency & accommodates ambiguous characters.
1987		IDENTIFY	K. Kuroda	CP/M & MS-DOS	Kuroda 1987	Microscopic wood ID; coded according to the IAWA Standard List (1981)	180 domestic Japanese hardwood species	Int. M-E Key intended for use alongside a microscope; does not allow character mismatches.
1988		COMEX	Y. Izumoto, T. Ojika, T. Hashimoto, & T. Higuchi	Microcomputers	Izumoto et al. 1988a	Macroscopic Japanese hardwood ID; derived from a program for general disease diagnosis	Japanese hardwoods (number unspecified)	Int. M-E Key that presents characters in order of frequency & hides irrelevant/redundant characters.
1988		Update of SOGEN	Y. Izumoto, T. Ojika, T. Hashimoto, & T. Higuchi	Microcomputers	Izumoto et al. 1988b	Macroscopic Japanese hardwood ID; update of SOGEN program to include character illustrations & descriptions	Japanese hardwoods (number unspecified)	Int. M-E Key that presents characters in order of frequency & provides illustrations & written descriptions for characters.
1990		Wood Identification Program 1989 (WIP89)	Jiaju & Fang	PC	Jiaju and Fang 1990	Wood ID, tree species indexing, & display of wood anatomical feature images	500 hardwood & 169 softwood species, primarily Chinese	Int M-E Key that allows searching families, genera, or species per-letter, displaying the character-code list, & showing example images of wood characters.
1990		Update of "Microcomputer-assisted Wood Identification System"	Y. Izumoto & S. Hayashi	PC	Izumoto and Hayashi 1990	Macroscopic Japanese wood ID & display of wood images & diagrams, aimed at beginner/non-expert wood anatomists	180 hardwood & 39 softwood species of Japan	Same as "Microcomputer-assisted Wood Identification System," w/ improvements: now an Int. M-E Key; allows backtracking to previous character inputs; includes tutorials w/ diagrams, microphotographs, & color surface images accessible during IDs.
1990		IDentification INformation EXpress (IDINEX)	W.Y. Lee & Su Kyoung Chun	DOS	Lee and Chun 1990	General taxonomic ID based on edge-punched card keys	Native Korean hardwoods & softwoods (number unspecified)	M-E Key that enables easy addition of new taxa & can process up to 229 characters per DB.

Supplement: Table S1. Summary of computer-aided wood identification programs (*continued*).

Date	Same-year historical milestones	Program name	Developer(s)	Platform or OS	References *	Purpose	Scope	Functionality
1990		CARDBOX-PLUS (CSIRO Macro Key)	CSIRO Australia	Windows, DOS, & CP/M	Ilic 1990	Hand lens wood ID w/ a focus on the southwest Pacific region & Australia	Woods primarily of the southwest Pacific & Australia (number unspecified)	Int. M-E Key that allows exclusion of characters, displaying the sequence of entered characters, & cancelling previous character inputs.
1991		Adaption of INTKEY	N. Espinoza de Pernia & R.B. Miller	Mainframe computers & microcomputers	Espinoza de Pernia and Miller 1991	Adaption of the IAWA List of Microscopic Features (1989) to the DELTA programs, including INTKEY	40 commercially important Venezuelan hardwoods	Int. M-E Key that allows entering multiple characters, obtaining possible matches at any time, & viewing useful features for distinguishing remaining taxa.
1993	World Wide Web became public domain	CSIROID	CSIRO Australia	MS-DOS	Ilic 1993; Wheeler and Baas 1998	Microscopic & hand lens wood ID; designed to replace CARDBOX-PLUS at CSIRO	Woods primarily of the southwest Pacific; 12 DBs including the CSIRO Family, Macro, & Eucalyptus keys	Int. M-E Key that provides detailed explanations of characters w/ a "feature help" option, allows removing entered characters, & provides "best subsequent features."
1994	Netscape 1.0 web browser released	Taxonomic Information Search System (TISS)	Su Kyoung Chun, M. J. Kim, & W. C. Lee	PC	Chun et al. 1994	Primarily for wood ID based on edge-punched cards, but can also be used to search DBs of physical & mechanical properties	Woods on Korean edge-punched cards (number & regions unspecified); includes DB of properties & uses for 382 tropical woods	Int. M-E Key that allows searching by scientific or common name, specifying mismatches, & searching data from multiple DBs at once.
1994	First smartphone IBM Simon released	UniWoods 2.0 (ENTRY2 and IDENT2)	O. Baumann	MS-DOS 3.0	Brunner et al. 1995	Two programs for hand lens wood ID; distributed w/ a reference manual w/ illustrated wood & character descriptions	115 hardwood species common to Guyana	ENTRY2 compares characters of a known wood to entries in the provided DB; IDENT2 keys out unknown characters.
1995	Amazon and Ebay launched; MS Internet Explorer released	Adaption of INTKEY	Institute for Wood Biology and Wood Protection, Federal Research Centre for Forestry and Forest Products (BFH)	Windows	Richter and Trockenbrodt 1995	Adaption of the DELTA programs, including INTKEY, for German & European hardwood ID & data storage/ retrieval w/ a German translation	180 commercial German and European wood species	Int. M-E Key that allows entering multiple characters, obtaining possible matches at any time, & viewing useful features for distinguishing remaining taxa.
1999	Blackberry 850 launched; Kyocera Visual Phone released w/ camera	Taxonomic Information Search System 2 (TISS 2)	Su Kyoung Chun	32-bit operating systems, including Windows 95	Chun 1999	Wood fiber ID using DELTA formatting, including microscopic fiber images; derived from TISS	124 fibers of hardwood & softwood species	Int. M-E Key that allows searching by scientific name & provides microscopic images of included fibers.
2000		Commercial timbers: descriptions, illustrations, identification, and information retrieval	H.G. Richter & M.J. Dallwitz	Web (https://tinyurl.com/5cxc6xry)	Richter and Dallwitz 2000 onwards; Silva et al. 2022	Adaption of the DELTA programs, including INTKEY, for international hardwood ID; provides example macroscopic & microscopic images of woods	409 internationally traded hardwood taxa	Int. M-E Key that allows entering multiple characters, obtaining possible matches at any time, & viewing useful features for distinguishing remaining taxa; includes detailed wood descriptions.
2000		Anatomy of European and North American Woods	A.G. Heiss	Web (https://tinyurl.com/57jw4c6m)	Silva et al. 2022; Heiss n.d.	Microscopic ID of European & North American woods, including illustrations	325 hardwood & 101 softwood species of Europe & North America	Int. M-E Key w/ example images & characters for palaeobotanical wood ID, including two DBs for modified & carbonized wood; currently defunct.
2001		Update of Wood Identification Program 1989 (WIP89)	Y. Jiaju, C. Fang, & L. HongJun	PC	Jiaju et al. 2001	Development of Wood Identification Program 1989 (WIP89) as an initiation of automated wood ID	570 hardwood & 171 softwood species, primarily Chinese	Same as Wood Identification Program 1989 (WIP89), w/ improvements: automated classification of softwood earlywood to latewood transitions & hardwood porosity domains.

Supplement: Table S1. Summary of computer-aided wood identification programs (*continued*).

Date	Same-year historical milestones	Program name	Developer(s)	Platform or OS	References *	Purpose	Scope	Functionality
2002	Friendster social network launched	macroHOLZdata	Department of Wood Biology, University of Hamburg & Holzfachschule, Bad Wildungen, Germany	PC	Heinz 2003; Silva et al. 2022	Hand lens wood ID, including images of woods from each plane of section; uses DELTA formatting	46 hardwood & 13 softwood commercial species (regions unspecified)	Int. M-E Key that allows querying of explanations & glossaries for wood biological & anatomical terms, structural features, properties, & applications.
2003	Myspace launched	Wood Database of the Forestry & Forest Products Research Institute	Forestry & Forest Products Research Institute, Ibaraki, Japan	Web (https://tinyurl.com/yvbkj4k3)	Silva et al. 2022; Forestry & Forest Products Research Institute n.d.	Microscopic ID of Japanese woods, including illustrations	781 Japanese woods	Int. M-E Key that includes features from the IAWA List of Microscopic Features (1989), w/ microscopic & macroscopic wood images.
2004	Facebook launched (Harvard only)	InsideWood	Libraries & Department of Forest Biomaterials of North Carolina State University, Raleigh, North Carolina	Web (https://tinyurl.com/3nenr9sw)	InsideWood 2004 onwards; Wheeler 2011; Wheeler et al. 2020; Silva et al. 2022	Microscopic ID of global woods, including illustrations	7849 global modern hardwoods, 2247 global fossil hardwoods, & 236 global modern softwoods	Three Int. M-E Keys for ID of modern hardwoods, fossil hardwoods, & modern softwoods; includes microscopic & macroscopic images of woods.
2004		Wood Anatomy of Central European Species	W. Schoch, I. Heller-Kellenberger, F. Schweingruber, F. Kienast, & D. Schmatz	Web (https://tinyurl.com/6pa82yvz)	Schoch et al. 2004; Silva et al. 2022	Microscopic ID of European woods, including illustrations	133 European hardwoods & softwoods	Microscopic ID key that lists characters for observation consecutively, including microscopic & macroscopic wood images & descriptions.
2005	YouTube launched	CITESwoodID	Institute of Wood Technology and Wood Biology, Federal Research Institute for Rural Areas, Forestry and Fisheries (vTI), Hamburg, Germany	Windows	Koch et al. 2011; Silva et al. 2022	Hand lens wood ID w/ a focus on CITES-listed woods; uses DELTA formatting	11 global hardwoods and 1 softwood listed in CITES, & 44 commercial look-a-like woods	Int. M-E Key that allows entering characters in any order & includes a character search bar; characters have detailed definitions, explanations for observation, & example images of woods.
2005		Key to a Selection of Arid Australian Hardwoods and Softwoods	J.A. Barker & B.A.H. Flinders	Web (https://tinyurl.com/3ryuarhj)	Silva et al. 2022; Barker and Flinders n.d.	Microscopic ID of Australian hardwoods & softwoods, including illustrations	58 Australian hardwoods & softwoods	Int. M-E Key that displays available & used characters, remaining taxa, & discarded taxa simultaneously; includes sub-keys for ID to species.
2009	ImageNet is created; Telia Sonera releases 4G network	I.D. Wood	Jordan Silberman	iOS (https://tinyurl.com/mrx4efvs)	Jordan Silberman 2009	Macroscopic ID of global woods, including illustrations, usage information, calculators & a glossary	205 global woods	Illustrated list of woods w/o a traditional key, but includes details on wood processing & utilization & a map for measuring land area.
2010	Apple releases iPad; Instagram launched	Brazilian Commercial Timbers	Forest Products Laboratory of the Brazilian Forest Service	Windows	Coradin et al. 2010; Forest Products Laboratory of the Brazilian Forest Service 2022; Silva et al. 2022	Adaption of the INTKEY program for Brazilian commercial wood ID	157 Brazilian wood species, primarily commercial	Int. M-E Key that allows entering multiple characters, obtaining possible matches at any time, & viewing useful features for distinguishing remaining taxa.
2011		Pl@ntWood	C. Sarmiento, P. Détienne, C. Heinz, J.-F. Molino, P. Grard, & P. Bonnet	Windows	Sarmiento et al. 2011; Silva et al. 2022	Microscopic ID of Amazonian hardwoods based on IDAO software, w/ illustrations	110 Amazonia hardwoods	Interactive ID tool w/ illustrations, designed to be user-friendly; uses a graphic interface and includes illustrated wood descriptions.

Supplement: Table S1. Summary of computer-aided wood identification programs (*continued*).

Date	Same-year historical milestones	Program name	Developer(s)	Platform or OS	References *	Purpose	Scope	Functionality
2014	VGGNet deep convolutional neural network released	CITESwoodID (web page)	H.G. Richter, K. Gembruch, & G. Koch	Web (https://tinyurl.com/jscf636b)	Richter et al. 2014 onwards; Silva et al. 2022	Adaption of the CITESwoodID program for hand lens ID of CITES-listed woods & look-a-likes, w/ illustrations	41 global CITES-listed woods & 31 commercial look-a-like woods	Int. M-E Key that allows entering multiple characters, obtaining possible matches at any time, & viewing useful features; includes detailed wood descriptions.
2016		macroHOLZdata (smartphone app)	Sven Koch	iOS (https://tinyurl.com/yc7se36a), Android (https://tinyurl.com/3cxdnays), macOS, & Windows	Sven Koch 2016	Adaption of the macroHOLZdata program for hand lens wood ID; uses DELTA formatting	153 global woods	Int. M-E Key that displays best & used characters, remaining taxa, & eliminated taxa simultaneously; includes illustrations, natural language descriptions, & a glossary of wood anatomical features.
2018		MyWoodPremium	Forest Research Institute Malaysia & Tunku Abdul Rahman University	iOS (https://tinyurl.com/yvxzdy8d)	INSTITUT PENYELIDIKAN DAN PERHUTANAN MALAYSIA 2018	Automated ID of Malaysian woods using computer vision	100 Malaysian woods	CVWID using a macro lens attached to the smartphone; requires internet.
2018		Xylorix Inspector	Agritix Sdn. Bhd.	iOS (https://tinyurl.com/u927ryfp) & Android (https://tinyurl.com/yc7ae5s6)	Agritix Sdn Bhd 2018	Automated wood ID using computer vision	45 woods from Malaysia, Madagascar, India, southeast Asia, Ghana, & France	CVWID using a macro lens attached to the smartphone; requires internet.
2019	Verizon released 5G network	AIKO-KLHK	Forest Products Research and Development Center, Bogor, Indonesia	Android (https://tinyurl.com/yc2tepac)	AIKO-KLHK Dev 2019	Automated ID of Indonesian woods using computer vision	823 Indonesian woods	CVWID using a macro lens attached to the smartphone; requires internet.
2020		Xylorix PocketWood	Agritix Sdn. Bhd.	iOS (https://tinyurl.com/yc6rczj7) & Android (https://tinyurl.com/5txxwkta)	Agritix Sdn Bhd 2020a, 2020b	Image-based macroscopic ID of global woods	455 global woods	Macroscopic wood ID by photographing the transverse surface of a wood w/o a macro lens, then comparing the image to included wood images; includes descriptions & uses of woods.
2020		CITESwoodID (smartphone app)	Sven Koch	iOS (https://tinyurl.com/yc6pcdyc), Android (https://tinyurl.com/ywtea8z5), macOS, & Windows	Richter et al. 2014 onwards; Sven Koch 2020	Adaption of the CITESwoodID program for hand lens ID of CITES-listed woods & look-a-likes, w/ illustrations	53 CITES-listed woods & 32 commercial look-a-like woods	Int. M-E Key that displays best & used characters, remaining taxa, & eliminated taxa simultaneously; includes illustrations, natural language descriptions, & a glossary of wood anatomical features.
2020		EyeWood	Wood Structure and Protection Innovation Team, Southwest Forestry University	Web (https://tinyurl.com/9ff7fu6f)	Southwest Forestry University 2020	Microscopic ID of hardwoods and softwoods; coded according to IAWA microscopic feature lists (1989, 2004)	7554 hardwoods & 356 softwoods (regions unspecified)	Int. M-E Keys for hardwoods & softwoods that display frequency of characters in remaining taxa, allow searching by family, genus, & species, & include taxa description pages.
2021		ID Maderas	United Nations Office on Drugs and Crime (UNODC)	Android (https://tinyurl.com/4xhzhbxh)	UNODC 2021	Hand lens ID of commercial Peruvian woods	20 commercial Peruvian woods	Two Int. M-E Keys: one for entering characters one-by-one & the other for entering any characters; includes glossaries for wood anatomical features & wood ID techniques.

Supplement: Table S1. Summary of computer-aided wood identification programs (*continued*).

Date	Same-year historical milestones	Program name	Developer(s)	Platform or OS	References *	Purpose	Scope	Functionality
2022		Xylorix Enforcer	Agritix Sdn. Bhd.	iOS (https://tinyurl.com/5du388bu) & Android (https://tinyurl.com/mupn632m)	Agritix Sdn Bhd 2022	Image-based macroscopic & automated wood ID; app suite that includes Xylorix Inspector & Xylorix PocketWood	465 global woods	CVWID using a macro lens attached to the smartphone (requires internet) & macroscopic wood ID by photographing the transverse surface of a wood w/o a macro lens, then comparing the image to included wood images.
2022	Open AI released Chat GPT	Brazilian Commercial Timbers (web page)	Forest Products Laboratory of the Brazilian Forest Service	Web (https://tinyurl.com/ywykp9fn)	Forest Products Laboratory of the Brazilian Forest Service 2022; Silva et al. 2022	Hand lens ID of Brazilian woods, including chemical & physical tests	275 Brazilian wood species	Int. M-E Key that displays available & used characters, remaining taxa, & discarded taxa simultaneously; includes macroscopic wood images & descriptions.
2024		WoodID App	Khanh Nguyen-Trong	iOS (https://tinyurl.com/4sbvht2n)	Khanh Nguyen Trong 2024	Automated ID of Vietnamese & African woods using computer vision	126 Vietnamese & African woods	CVWID using a macro lens attached to the smartphone; does not require internet.
2024		Wood Identifier: AI Scanner	Richard Schoerner	iOS (https://tinyurl.com/68yy4p27)	Richard Schoerner 2024	Automated wood & tree ID using computer vision	Woods & trees (number & regions unspecified)	Computer vision wood & tree ID w/o a macro lens attachment; requires internet.
2024		WhatWood? Central America Edition	Kyatt Spessert	iOS (https://tinyurl.com/4wxvxvzd), Android (https://tinyurl.com/59vp52hr), & macOS	Arévalo and Wiedenhoeft 2022; Kyatt Spessert 2024	Hand lens ID of Central American, Mexican, & Caribbean woods based on the *Identification of Central American, Mexican, and Caribbean Woods* field manual	138 Central American, Mexican, & Caribbean hardwoods, softwoods, & monocots	Dichotomous key that includes example images of woods for each decision couplet; provides instruction on performing macroscopic wood ID w/ a hand lens & explanations of wood anatomical features.
2025		WhatWood? Ghana Edition	Kyatt Spessert	iOS (https://tinyurl.com/4w4bmdhd), Android (https://tinyurl.com/yr87vx29), & macOS	Arévalo et al. 2020; Kyatt Spessert 2025; Author et al. *submitted*	Hand lens ID of Ghanaian woods based on the *Field Identification Manual for Ghanaian Timbers*	87 Ghanaian hardwoods, softwoods, & monocots	Dichotomous key that includes example images of woods for each decision couplet; provides instruction on performing macroscopic wood ID w/ a hand lens & explanations of wood anatomical features.
2025		Wood Id – Wood Identifier	iOS: Upasana Deshmukh Android: TLUTech	iOS (https://tinyurl.com/mtcw3skz) & Android (https://tinyurl.com/59xr954h)	Upasana Deshmukh 2025; TLUTech 2025	Automated wood ID using computer vision	Number & regions of woods unspecified	CVWID w/o a macro lens attachment; requires internet.
2025		Wood Identifier: AI Scanner (Artmvstd)	Artmvstd	Android (https://tinyurl.com/5xu2xxfs)	Artmvstd 2025	Automated ID of global woods & trees using computer vision	Global woods & trees (number unspecified)	Computer vision wood & tree ID w/o a macro lens attachment; requires internet.
2025		Wood Identifier AI Scanner (Nikhil Kumar)	Nikhil Kumar	iOS (https://tinyurl.com/ynj6dbh5)	Nikhil Kumar 2025	Automated ID of global woods using computer vision	Over 500 global woods	CVWID w/o a macro lens attachment; requires internet.
2025		Wood Identification App	DDR Technologies INC	Android (https://tinyurl.com/ykfr2ssx)	DDR Technologies INC 2025	Automated ID of global woods using computer vision	"Thousands" of global woods	CVWID w/o a macro lens attachment, including written explanations of model reasoning; does not require internet.

ID: Identification. M-E Key: Multi-entry key. Int. M-E Key: Interactive multi-entry key. Non-Int. M-E Key: Non-interactive multi-entry key. DB(s): Database(s). CVWID: Computer vision wood identification

* References can be found at https://github.com/MSU-WhatWood/Table-S1-References.