New Digital Soil Tools Available for Forest Scientists and Managers

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Abstract

Soil information is essential for identifying appropriate tree species to manage, selecting appropriate silvicultural methods, and planning timber harvests. Traditionally, soil information was available in paper copies of soil surveys, and more recently in digital form via Web Soil Survey. However, newly available soil information tools provide interactive access to digital soil information and interpretations. We describe several different soil information tools that provide access to soil survey information and interpretations in an interactive framework, including SoilWeb, SoilWeb Earth, and the Soil Properties viewer. Each tool is an interactive web-based computer application that facilitates access to and use of soil survey data on personal computers, tablets, or phones.

INTRODUCTION

Foresters recognize that soil information is essential for managing forest land. Soil maps and associated soil property information are needed for delineating stands, identifying tree species suited for the site, selecting appropriate regeneration methods, and protecting soils from compaction, rutting, and erosion during harvesting operations. However, despite the recognized importance of soil information in forestry, accessing and using soil information has historically been challenging for non-soil scientists due to the inherently complex, multidimensional nature of soils and limitations with conveying soil information in traditional paper soil surveys.

The most comprehensive inventory of soils in the United States is the Soil Survey Geographic database (SSURGO). Historically, access to SSURGO was limited to paper copies of soil surveys published by county or national forest. More recently, the Web Soil Survey (USDA Natural Resources Conservation Service 2017) was developed to deliver a wider array of soil information digitally. This powerful software can be used to produce soil maps and reports about specific soil properties and identify the suitability of soils for various land use practices. It also provides the means for downloading SSURGO data to be used in other applications such as with geographic information systems (GIS) or in other databases. However, this software requires users to possess considerable technical knowledge about soil terminology and about SSURGO for it to be used effectively.

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Recently, several new software tools have been developed that provide an interface between SSURGO and soil information users. These new tools include SoilWeb, SoilWeb Earth, and the Soil Property Viewer (O'Geen et al. 2017). There are additional applications (apps) including the Soil Data Explorer and the Soil Extent Viewer that run within them or stand alone. These software tools provide access to the SSURGO database in a user-friendly, intuitive, and interactive way which helps convey complex soil information more effectively than a traditional soil survey or the Web Soil Survey. The objective of this paper is to describe these different tools, illustrate how they can be used to better inform foresters, and show how they can be applied in forestry applications.

SOILWEB

SoilWeb (https://casoilresource.lawr.ucdavis.edu/soilweb-apps/) is an app which provides an interactive interface to SSURGO that can be used with a web browser on a desktop or laptop computer, a tablet, or a cellular phone. There also is a native SoilWeb app for Android and iOS devices (users can check the app store on their device for SoilWeb produced by the University of California, Davis). When used on a phone or tablet, the app displays one or more soil profiles based on the user's location with profile sketches that are generated from the best available data in SSURGO. The browser version displays interactive soil maps and can also be used on a phone, tablet, or computer. The phone app version lacks these maps but includes access to all other SSURGO data and a link to the browser version.

The following SoilWeb description and figures are focused on the browser version because this version includes the interactive soil maps. With the browser version, the Leaflet web mapping library is used to provide an interactive means for exploring and querying soil maps. This interface allows users to select one of the following three ways to locate a point on the map: using web browsing software to geolocate the user's computer; typing in an address, ZIP Code™, or landmark; or entering the latitude and longitude. Stable links to specific locations (WGS84 coordinates) and zoom levels are provided in the navigation bar or copied to the clipboard when the user right-clicks on the map.

Several base maps can be displayed, including satellite imagery with map unit (soil polygons) superimposed and an option to display road names and natural features like rivers and streams (Fig. 1A). There also are options to select U.S. Geological Survey (USGS) or Esri (Esri, Inc., Redlands, CA) topographic base maps with soil unit boundaries superimposed (Fig. 1B).

By selecting a location on the soil map, a summary is displayed that provides information about the map unit name, symbol, primary soil phase, slope class, and expected soil components found within. A soil component is typically named for a soil series[2] but can represent more generic concepts such as a family or subgroup taxon from Soil Taxonomy.

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[2] A soil series concept encompasses a relatively narrow range of soil physical, chemical, and morphologic properties (as a suite of genetic horizons) that give rise to similar use and management considerations. The soil series is also the lowest category in Soil Taxonomy.

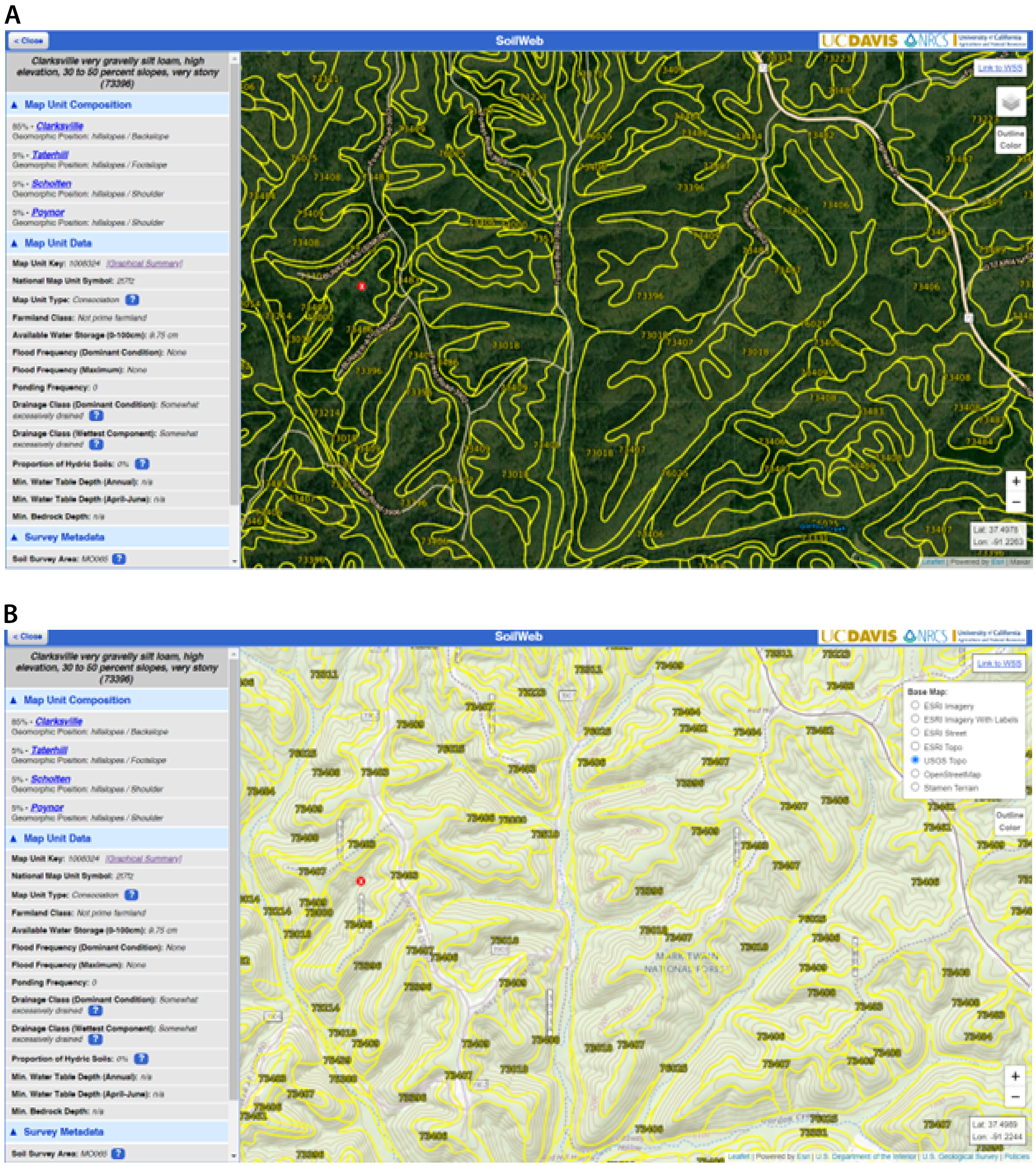


Figure 1.—Base map display including satellite imagery (A) and topographic map (B).

This summary also includes the typical arrangement of components by geomorphic or hillslope position, estimated areal proportions, and the map unit type—a classification of spatial complexity relative to mapping scale (Fig. 2). The ability to show multiple soil components, their expected proportion, subgroup level classification, geomorphic clues, and drainage class is an exceptionally important feature because it conveys soil variability in a very intuitive way. By selecting the drop-down menus, additional information about the map unit is displayed.

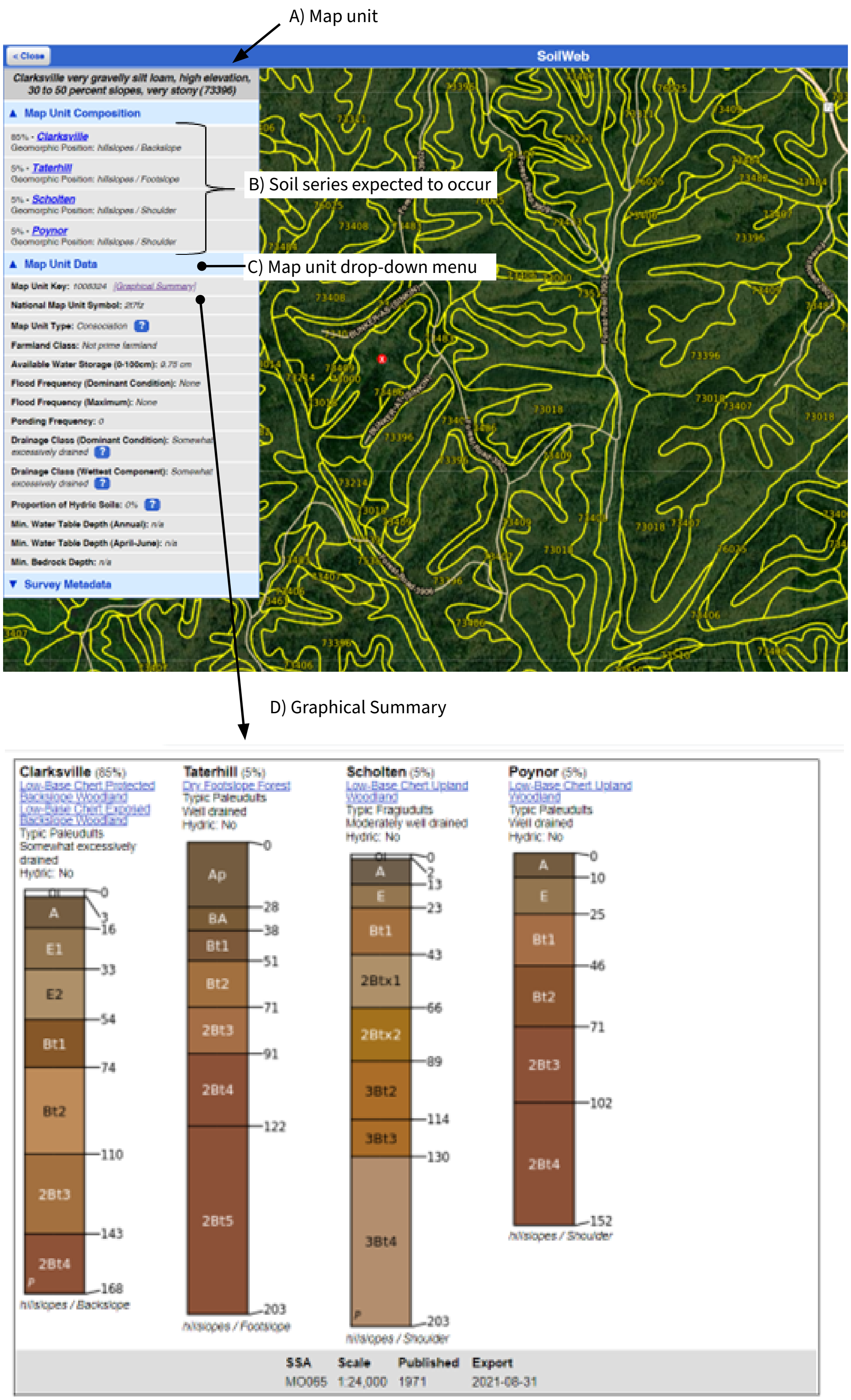
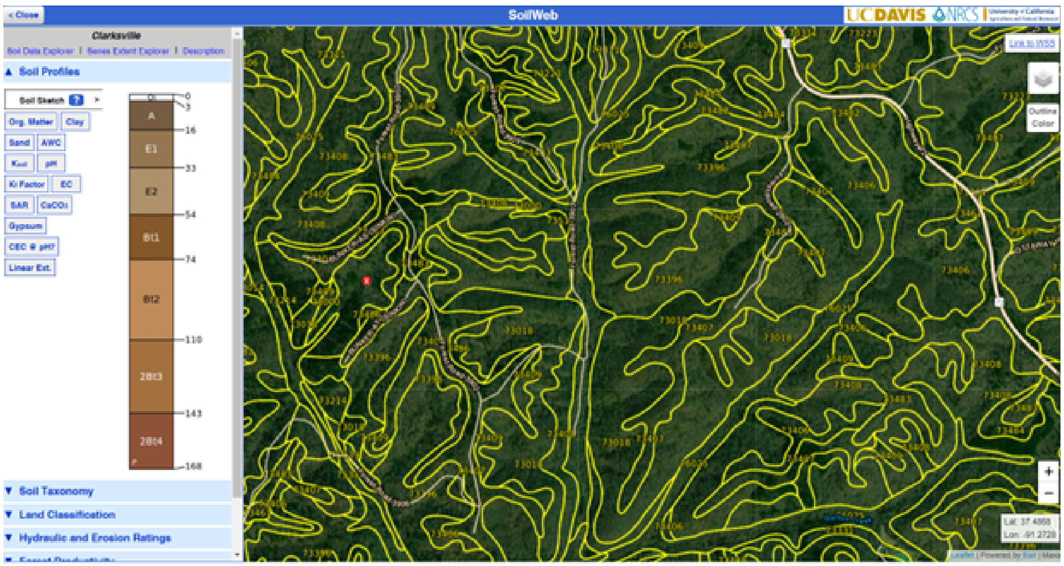


Figure 2.—Map unit (soil polygon) summary (A) of map unit components, which are often correlated to soil series (B) in the drop-down menu (C), and graphical summary (D).

When a single soil component is selected, a stylized soil profile "sketch" is displayed to illustrate soil horizons and their colors (Fig. 3A). This is particularly useful in forestry applications for identifying the types of genetic horizons within the profile (indicative of soil formation processes), the presence of root-restricting layers (e.g., a fragipan; Fig. 3B), or drainage restrictions indicated by the presence of gleyed (gray-colored) horizons. Soil profile sketches are generated from field descriptions when available (also called component pedons); otherwise, sketches are generated from Official Series Descriptions. Sketches for higher-taxa components (e.g., subgroup-level classification) are created directly from SSURGO records, which do not contain representative soil colors. A suite of commonly used soil properties can be selected and displayed graphically or in table form. Hyperlinks provide additional information about the soil sketches.

A



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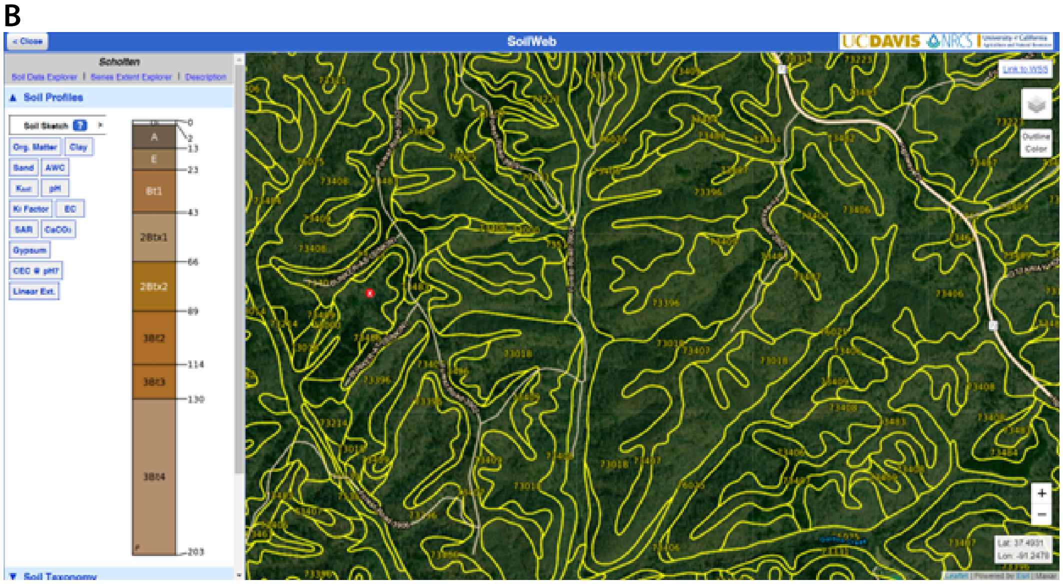

Figure 3.—Soil profile sketches (A and B). A soil with a fragipan or fragic conditions is indicated by the "Btx" horizons (B). Hyperlinks are used to access additional information.

Other pull-down menus on the left (Fig. 4A,B) provide access to important information for practicing foresters. Key menus include the:

- **Soil Taxonomy** menu, which provides classification information to the series level for including in forest management plans.

Figure 4.—Drop-down menus for **Soil Taxonomy** and **Land Classification** (A) and **Forest Productivity** and **Soil Suitability Ratings** (B).

- **Land Classification** menu, which provides the Ecological Site Description and information about expected plant communities associated with the soil map unit as well as common vegetation states under different land uses and management practices. In the eastern United States, Ecological Sites are analogous to the Ecological Land Types developed by the USDA Forest Service (Iverson et al. 2019). More information about Ecological Sites can be found by selecting the hyperlink. This menu also gives organic carbon pools, which can be useful for understanding potential impacts of forest operations.
- **Hydraulic and Erosion Ratings** menu, which includes the erosion tolerance (T-Factor), runoff rates, soil drainage class, hydric rating, and the Hydrologic Group (used in runoff models). The total Plant Available Water rating is also included, which provides an estimate of water storage, and is an important metric needed for predicting forest regeneration potential (Kabrick et al. 2014), stand development patterns, and total productivity (Kabrick et al. 2008). On the browser version, hyperlinks provide access to more information about these ratings.
- **Forest Productivity** menu, which provides site index information associated with individual soil series where suitable site index trees were available (for suitability criteria, see Carmean et al. 1989). Productivity estimates (cubic feet per acre per year) are also provided and are similar to those by Schnur (1937).
- **Soil Suitability Ratings** menu, which provides links to various land uses, including Forestry ratings related to planted seedling performance; rutting and erosion associated with harvesting, road construction, and log landing use; and risk associated with windthrow, diseases, and droughts. Information about seasonal rutting hazard is also included and this information can help determine the best seasons for logging operations. Criteria for developing these ratings are available in the "National Forestry Manual" (Natural Resources Conservation Service Staff 1998). For the Central Hardwood region, there is a Black Walnut Suitability Index that can be used for identifying suitable soils for growing this species. This index was developed using published information about site factors known to affect black walnut (*Juglans nigra*) growth, including soil texture, drainage class, flood frequency, soil depth, pH, plant available water, and historical vegetation (Wallace and Young 2008). A suitability rating using a similar framework is planned for improved northern red oak (*Quercus rubra*) stock.
- **Details** menu, which provides additional information about soil properties and a link to the National Cooperative Soil Survey Data Mart for downloading laboratory characterization data.

The same pull-down menus can be found in the SoilWeb phone app by selecting a soil component and then selecting the "details" link on the bottom of the screen.

SOIL DATA EXPLORER

The **Soil Data Explorer** (Fig. 5A–D) provides links to several tabs with important soil information for foresters. The first tab provides a link to the **Official Series Description** (OSD; Fig. 5A). The OSD provides a succinct narrative about parent material, drainage, and permeability, as well as a detailed description of a representative pedon for the selected series. It also provides context by identifying other soils that are typically mapped with the featured soil and the key properties distinguishing it from other soil series. The OSD is the most comprehensive information source for learning about a specific soil series.

The **Lab Data** tab (Fig. 5B) provides a link to aggregated data for selected chemical and physical properties for all pedons correlated to the selected soil series. It also provides the median, the 5th percentile, and the 95th percentile by depth for each property, indicating range of variation that can be expected for each of the soil properties. Here foresters can quickly get estimates of the amount of stored carbon, the pH and base saturation, and the cation exchange capacity by depth for entire soil profiles. These properties are important for assessing nutrient storage potential and depletion risk caused by harvesting, prescribed burning, and other forest management activities where trees and other vegetation biomass are consumed or removed.

The **Water Balance** tab (Fig. 5C) was introduced in 2022, and provides average monthly precipitation, potential evapotranspiration (PET), and soil plant available water storage, and the resulting monthly expected soil water availability. Precipitation data are based on PRISM 30-year averages and PET is estimated by Thornthwaite's (1948) method. The water storage estimate is from SSURGO. Available water storage is estimated using a "leaky bucket" style model (Arkely and Ulrich 1962) that accounts for soil drainage in addition to net changes in soil water due to inputs from precipitation and losses from evapotranspiration. The water budget provides an estimate of the plant water availability for the soil during a typical year and identifies the time of year when water deficits are expected and when recharge normally occurs.

The **Sibling Summary, Competing Series,** and **Shared Subgroup** tabs provide information about how the selected soil series is related taxonomically to other soil series, which may be of more interest to pedologists and other soil classifiers than to foresters. However, the **Block Diagrams, Map Units,** and **Extent** tabs provide insight into where in the landscape a series is expected to occur, the map units associated with the series, and where the series is mapped (Fig. 5D). This information is particularly useful for foresters working on large districts or with private landowners where first-hand knowledge and experience with forests on specific groups of soils can be transferred elsewhere in the region where the same or similar soils occur.

SOILWEB EARTH

SoilWeb Earth (https://casoilresource.lawr.ucdavis.edu/soilweb-apps/) runs on the Google Earth platform to overlay soil map unit boundaries on satellite imagery. It has similar functionality as the browser version of SoilWeb and has the added advantage of providing access to point data from sampled pedons stored in the National Cooperative Soil Survey Soil Characterization Database. Other benefits of SoilWeb Earth are its utilization of Google Earth's high-resolution satellite imagery, its three-dimensional rendering of the landscape, and access to SSURGO data from map unit to regional scales.

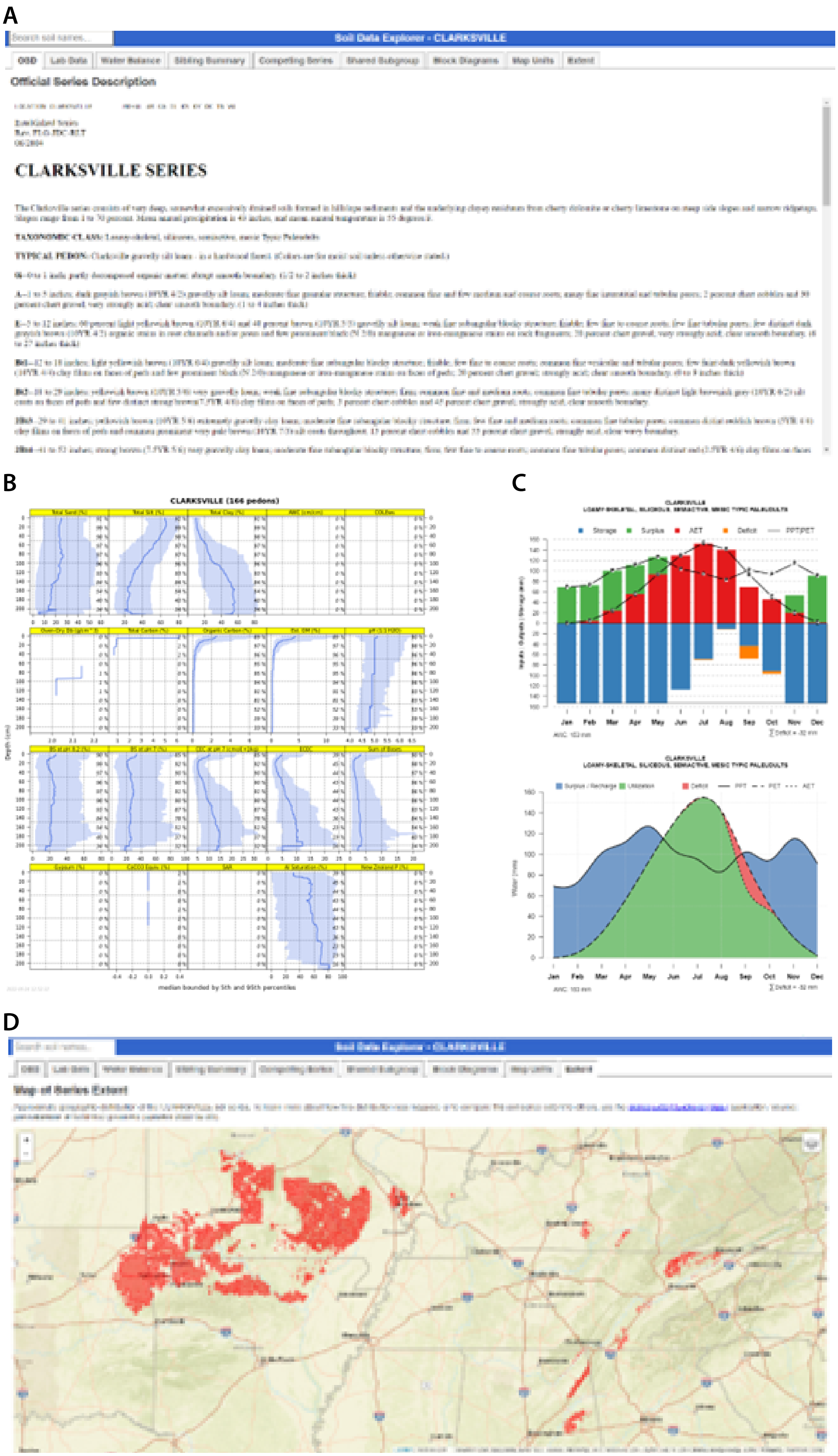

Figure 5.—Soil Data Explorer tabs for the Official Series Description (A), Lab Data (B), Water Balance (C), and Extent (D).

SOIL PROPERTIES VIEWER

The Soil Properties viewer (https://casoilresource.lawr.ucdavis.edu/soil-properties/) (Fig. 6A,B) allows users to examine chemical and physical soil properties from local to national scales. The soil properties are derived by aggregating map unit-scale data from SSURGO to create spatial datasets at a 2,624 foot (800 meter) grid resolution. The grids use an Albers Equal Area projection centered on the continental United States and the NAD83 datum (EPSG:5070).

The information provided by the viewer is particularly useful for examining regional and national patterns in soil properties. The soil property data can also be downloaded in a GeoTIFF format and, with appropriate software, linked to other data to examine relationships between soil properties and forest vegetation. For example, Figure 6C shows the negative relationship between soil pH and the abundance of black birch (*Betula lenta*) in the eastern United States. The abundance of black birch was derived from USDA Forest Service Forest Inventory and Analysis (FIA) data, scaled to the same grid resolution as the GeoTIFF of soil pH.

DISCUSSION AND CONCLUSIONS

SoilWeb and associated applications are an intuitive and interactive suite of tools for accessing SSURGO data. They provide a powerful means for assisting foresters to quickly identify and obtain technical information about soil map units, soil properties, and interpretations. These tools offer alternative means for accessing SSURGO data compared to Web Soil Survey, an app which can be used to produce customized reports for specific locations. In contrast, SoilWeb is a data-focused interface for exploring soils and soil properties. It uses integrated data panes to provide soil properties in graphic or tabular form along with the soil map in the background. This facilitates a rapid understanding of soil information, which often is complex and difficult to visualize.

SoilWeb source data are based on an annual snapshot of SSURGO, updated October 10 each year. However, the apps themselves are continually being updated and data products are rapidly evolving, with new components and applications being developed regularly. Because the tools can be used on a variety of platforms, they can be used in the office or in the field, wherever an internet or data connection is available.

Throughout the Central Hardwood region, SSURGO data are available and accessible with SoilWeb and associated apps. A comprehensive list of soils networks and resources (including those described here) can be found in Appendix B of "Forest and Rangeland Soils of the United States under Changing Conditions" (https://www.fs.usda.gov/treesearch/pubs/61256).

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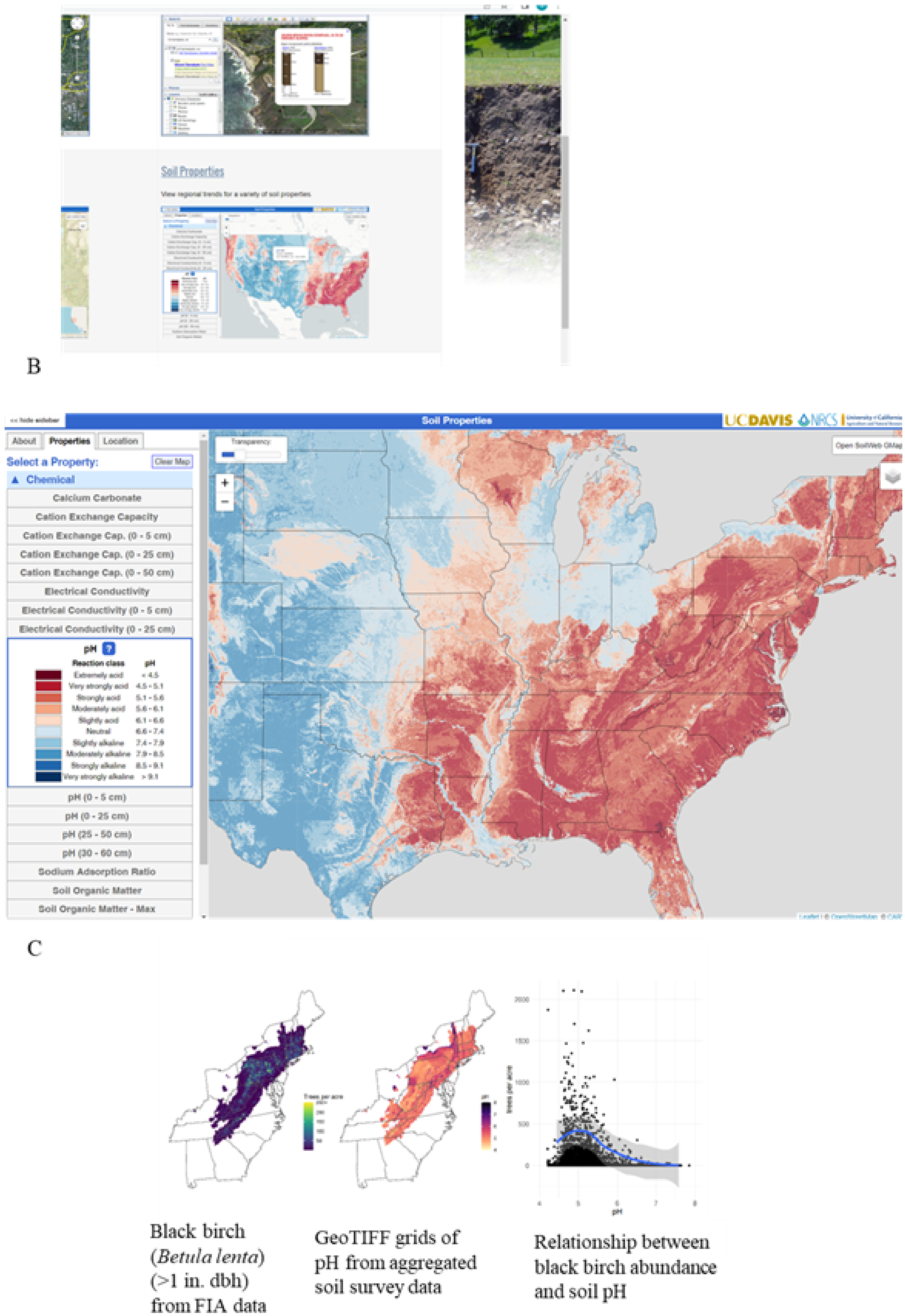

Figure 6.—Soil Properties viewer location on the UC Davis California Soil Resource Lab website (A); regional trends in soil pH shown in the viewer (B). Downloaded soil data from the Soil Properties viewer were used to examine relationships between soil pH and black birch (*Betula lenta*) abundance (C); dbh is diameter at breast height and FIA is the Forest Service's Forest Inventory and Analysis program.

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The content of this paper reflects the views of the author(s), who are responsible for the facts and accuracy of the information presented herein.

CITATION: Kabrick, John M.; Lawson, Shaneka S.; Beaudette, Dylan; Indorante, Samuel J.; Vickers, Lance A. 2024. **New digital soil tools available for forest scientists and managers.** In: Thomas-Van Gundy, Melissa; Adams, Mary Beth, comps. Proceedings of the 22nd Central Hardwood Forest Conference: managing future forests today. Gen. Tech. Rep. NRS-219. Madison, WI: U.S. Department of Agriculture, Forest Service, Northern Research Station: 88–100. https://doi.org/10.2737/NRS-GTR-219-paper10.